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RAYMOND OLNEY
Editor and Business Manager

EDITORIAL

The Development of Designers

A CHIEF engineer of at least one farm equipment manufacturer is concerned that "'so few of our young men are willing to pay the price to become good designers of farm equipment".

That price is the long term of intensive detailed work required to master a creative art based on a large body of science. It usually means a long apprenticeship of running interference, at the stage of the young engineer's career when he is apt to be most impatient to be carrying the ball.

Truly the demands upon a designing engineer are formidable. He must know how machines have been made in the past; the variety of ways in which they are being made; the scientific, economic, manufacturing, trade, and functional reasons for their being made in certain ways.

To work effectively he must maintain a mental index for quick reference to the specific current data he may need at any time from the large and changing total body of available data in the fields of engineering, physical and biological science, manufacturing practice, and user experience.

At one and the same time he must both stimulate and discipline the growth of his originality. He must develop the capacity to visualize and to evaluate the possibilities of new combinations, extensions, and applications of science. He must develop the knacks of creating new and improved designs in his mind, setting them out clearly on paper, and following them through construction and tests.

In our engineer-made material civilization there will be difficulty in popularizing on its own merit, the added rigorous discipline for a beginning designer, of living for a few years on what he is currently worth to his employer. Possibly something could be done by putting this employment on an industrial fellowship basis, or otherwise providing for wider recognition of the fact that the beginning designer has elected to hoe a long row toward a future goal.

It occurs to us that more young agricultural engineers would be willing to pay the price if they could have more assurance in their student days that they have the aptitude for success in mechanical design, and if they could be shown that the rewards of success are worth the cost.

Suitable apitude tests are available. It appears that conditions may warrant their more extensive use.

As to the rewards of success, we believe that most engineering students have the opportunity to gain some appreciation of the ultimate satisfactions and advantages of a career in engineering. In ultimate rewards, design compares favorable with other forms of engineering work. Most agricultural engineering graduates are farm boys who are not afraid of work. The apparent obstacle which keeps many from aiming at careers in design is the poor prospect for early tangible progress and accomplishment.

Several recent graduates with whom we have talked have indicated a hesitance to develop or show ability as draftsmen, for fear of being held to the drawing board at low pay for the better part of their lives.

There are two apparent ways in which the immediate cash cost to the individual, of training to be a good designer, might be decreased.

One is for adequately financed employers to continue the trend toward higher paying apprenticeships, as an investment in the future productivity of the employees concerned. Selection of candidates based on aptitude tests, suitably long-term employment contracts, and insurance could help to protect the investment.

The other may be more difficult from technical and personal relationship standpoints, but may also be more in keeping with the spirit of engineering. It requires deliberate attention to possible means of increasing the rate and efficiency with which the designer learns his art, and to possible means of increasing the value of his output while learning. It is based on the idea that those who consider mechanical design an open field for engineering progress might also consider current means of attracting and developing potential designers to be similarly subject to improvement.

Design must compete with other outlets for engineering talent. But it is too important to the whole field of engineering progress, we believe, to risk leaving the competition to chance. It will be to the professional interest of engineers and the financial interest of employers to encourage design in a manner to attract a liberal share of potential design talent.

Factors in Progress

A GEOMETRIC progression of advancement in agricultural engineering appears to be under way.

With stronger backing, and more demand for their services, more agricultural engineers are working in more areas and from more different viewpoints with the help of more and better technology; with better tools, materials, and components made available by other branches of engineering; and with more cooperation from agricultural groups, to advance engineering service to agriculture at a more rapid rate than ever before.

Deflationary adjustments and other factors beyond the control of agricultural engineers may be expected to slow down this rate of progress at some future time.

A number of factors in the continuing opportunity for agricultural engineers, however, are largely subject to their own control.

Agricultural engineers can continue to direct their efforts toward increasing efficiency and other sound applications which prove of greatest value when the economic going gets tough.

They can exercise a selective and shaping influence on the character of young men training for and starting careers in agricultural engineering.

They can continue to improve and to make the most of their technology, and of helpful progress in related fields.

They can continue to invite and encourage the cooperation of related groups on whom their success in part depends.

The present is hectic with immediate demands which leave little time for contemplation of the future. But it is also a time to build strongly with professional character, economic and technical soundness, and genuine service, toward a position from which continued progress will be possible at any future time when factors beyond the control of agricultural engineers may be less favorable.

Unit Operations

RECENTLY one agricultural engineer indicated that the technique of looking at agricultural engineering problems in terms of "unit operations" or "unit processes", as the case might be, is not being used in research, design, development, teaching, and other activities as fully as its potentialities might suggest.

Perhaps it is taken for granted by many experienced engineers, to the extent that they may fail to bring its methods and advantages to the attention of their students and understudies. Its merit is the same elementary simplicity which may cause it to be overlooked, or used loosely as rule-of-thumb procedure without realization of its full advantages.

The unit operations concept is simply one way of classifying the primary factors in an engineering job to be accomplished.

It is a way of classifying these factors according to functions and functional units. It is a way of insuring consideration of physical functions as primary factors in engineering analysis.

The "unit operations" concept of combining grain, for example, might picture the whole operation as essentially a series of consecutive operations including shearing; material moving and positioning; mechanical *(Continued on page 116)*

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Basic Requirements in the Design and Development of the Self-Propelled Combine

By Tom Carroll

THE idea of a self-propelled combine is not at all a new one, several attempts having been made to produce one over a long period, some with little success, others with more promising results. Many of these were combinations worked out by farmers to meet their specific requirements; others had been designed by farm implement companies. None, however, gave any indication of universal acceptance of the principle, and with the general ownership of tractors, there was little or no articulate demand for such a machine.

When, following our idea that there was a definite place for such a machine, particularly in the Argentine, where horses being plentiful were still used in great numbers to pull combines, we decided that the following essentials had to be borne in mind:

1 That the machine should have a width of cut and capacity suitable for large farms.

2 That the cutter bar should be mounted ahead of the machine.

3 That the motor should be mounted where its power would give greatest efficiency for both traction and operation, and be readily accessible.

4 That the motor should have sufficient horsepower to propel the machine and operate the cutting and threshing mechanism.

5 That every effort be made to get an even distribution of the weight over the two main driving wheels, with the necessary weight on the steering wheels to give the required control.

6 That the operator's seat and the location of all the controls be so placed that one man could handle the combine.

Our first self-propelled combine was a 16-ft model and was put on the market in 1939. Although designed to meet Argentine conditions, we soon discovered that the idea appealed in other countries too. Farmers said it was what they had been waiting for, and we found that there was nothing to the statement that a farmer would not buy a self-propelled combine and leave his tractor idle on the farm, when he began to see that the advantages of the self-propelled were such that he could afford to leave his tractor idle.

The success attendant on our introduction of the self-propelled machine indicated to us that we should proceed with a model of size and price that would be suitable for most farmers, and so we designed and built a lighter and less expensive machine with a 12-ft and 14-ft cut, and found that it met with general acceptance in practically all the grain-growing countries of the world.

Keeping all of the above requirements in mind and going back over our own experience, we have come to the conclusion that the basic requirements and the problems that the engineer must meet in today's design of self-propelled combines can be considered in the following order:

1 Accessibility

2 Simplicity, with easier and simpler adjustments

3 Complete ease of control and comfort for the operator

4 Capacity to harvest all and every condition of crop encountered throughout the grain-growing countries of the world

5 Lighter weights and greater capacity in relation to width of cut

6 Speeds from ½ mph to a maximum working speed of 5½ mph with a road speed of 7 mph

7 Sufficient engine power to take care of difficult ground conditions as well as to operate the combine mechanism

8 Proper weight distribution in relation to wheels

9 Attachments, drives, and straw-handling equipment

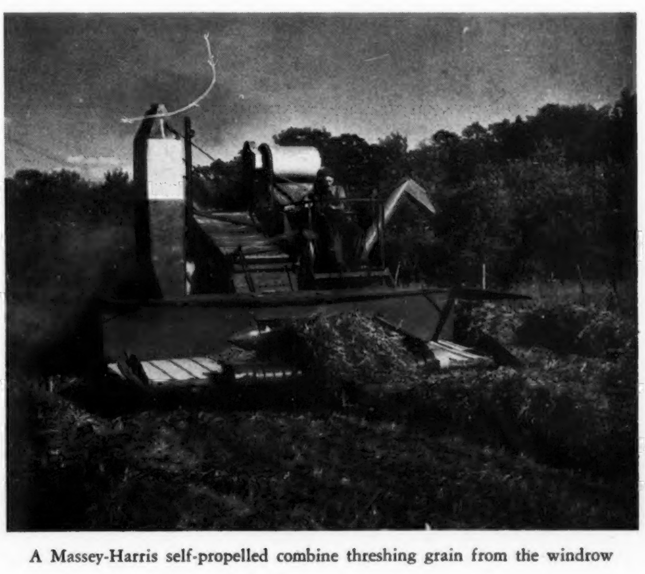
10 Necessary traction equipment for rice fields.

I will comment on each of these items in the order given:

Accessibility. Individual designers will have their own ideas about accessibility. Maybe some day we shall design a combine that is so foolproof that it will never choke or run into any mechanical difficulties while in the field, but until that day has been reached we feel that it is necessary to make provision to take care of the troubles produced by inexperienced operators and difficult field conditions. Therefore, we look upon accessibility as a very important factor in design.

Simplicity. Something that looks simple usually is simple. Something that looks easy to operate usually is easy to operate, so we get back to a basic state of the operator's mind. By simplicity we have in mind chiefly the question of ease of adjustment, and reducing these adjustments to the fewest number possible. It is surprising how few adjustments are absolutely necessary if we set out to eliminate all unnecessary ones.

To illustrate better the effect of unnecessary adjustments in the mind of the farmer, I can recall a little episode which happened one morning many



A Massey-Harris self-propelled combine threshing grain from the windrow

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Power and Machinery Division.

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years ago in the Argentine. While travelling through the country I happened to call on an agent, more with the idea of renewing acquaintance than with any other thought in mind. To my surprise, he had one machine which he couldn't deliver, and he prevailed upon me to go out and check this machine, with the idea of satisfying the farmer, and getting him to change his mind about returning the combine.

This particular work was not on my program for that day, and very much against my will I went out with the agent to see what the trouble was. On arrival at the farm, and after looking over the machine, we found that every adjustment on the combine was set in the most unfavorable position for good work. Not being in the best of humor at the time, my comments to the farmer were, "What the hell did he have this particular adjustment in this particular position for", and so on all around the machine.

The farmer, following me, and patiently listening to my "what the hell" comments until his patience became exhausted, suddenly turned around to me and said in Spanish, "Vamos, Senor! que tanto diablo respecto a los ajustes. En ultimo caso para que diablos los puso si no eran para usar!" Which translated freely in English means, "Say Mister, I listened to enough of what the hell about the adjustments, but what I would really like to know is, what the hell did you provide the adjustments for if you did not intend me to use them." I need hardly mention that after correcting the adjustments and showing the farmer how to get more value out of his machine, we parted very good friends.

From that day forward, we have put a great deal of effort into eliminating unnecessary adjustments of which there were plenty on all early pull-behind combines. The ideal is to have the necessary adjustments so arranged that the machine will do good enough work even if adjustments are misused.

Ease of Controls and Comfort for Operator. We believe that designers must keep this item very much in mind. A farmer operating his combine all day where the controls are all easy to operate, and the machine handles nicely in the field, will arrive home feeling that he has accomplished a good day's work, and he will look forward to the amount of work he is going to do the following day. However, if he feels his machine is difficult to control, and if he is tired out at the end of the day, he will not have a good word for the designer nor the company who produced the machine.

I would like to mention here the importance of good visibility. The operator should sit with all controls readily accessible and with a clear view of the cutter bar and the field.

The man who likes to operate his own combine and finds it a pleasure to drive it is the best salesman any company can have. Individual designers will have their own theories on simplicity of controls. However, the object to be achieved is to have a combine that everybody wants to drive, because it drives just like a modern motor car, comfortable and easy on the operator.

In listening to farmer comments we often hear the following in reference to the design of farm machinery: "If the factory engineers would only come out to the farms and see our conditions, they might design something different to what they send us now." Or the often-heard comment of farmers, "If we could go back to the factories, we would show them what to design". Sometimes on further questioning of the men who use farm machines, we get some good leads as to what they require, and the successful designer pays very close attention to farmer opinions.

Referring again, in a lighter vein, to ease of control and the comfort of the operator, we note a variety of different operator conditions as we travel up and down and around the world — for example, the Argentine operator with his balloon trousers and rope-soled slippers, the Arab with his flowing skirts to get caught in the drives, the stolid British farmer who will cut a square corner no matter how long it takes, the Hollywood actor turned custom operator, and the farm girl turned into a vamp a la Dorothy Lamour. With such things to distract the operator's attention, you will see how important simple controls and the comfort of the operator becomes.

Capacity Requirements to suit every condition throughout the grain growing countries of the world. Individual companies will have their own ideas of the sizes and capacities of machines that they would like to develop. Our own experience has indicated that, if we are to reach all countries of the world, certain basic sizes of machines are required. We might group these combines in three categories: (1) machines suitable for large farms and custom operators, (2) machines for medium-size farms, and (3) machines for the small farms — 7-ft cut.

In the first two categories, we believe that varying widths of platforms are essential to suit different requirements, such as a machine with a 16-ft cut for the plains would of necessity be 12-ft cut for irrigated land or countries growing heavy crops, the idea being that all operators want to operate their machines at the same ground speed in the field. The traction speed variations should take care of the different size machines for varying local crop conditions.

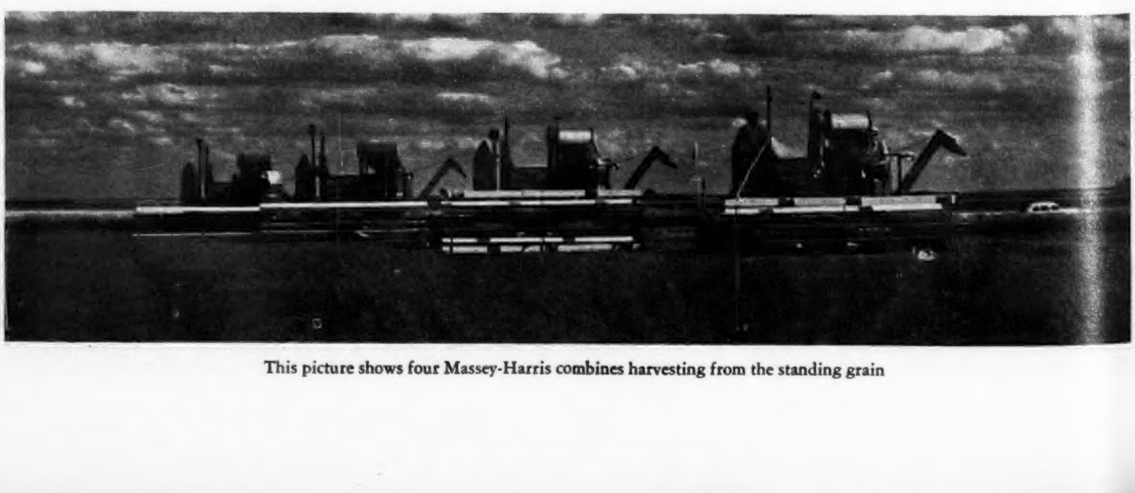
Referring to width of cut, we often hear the comment in European countries that American designers only design machines for the light crop plains areas of the U.S.A. and pay no attention to European heavy crops and long straw which they want to cut close to the ground to save all the straw.

We might say that these heavy crops and long straw areas must be kept in mind by designers who wish to see their design sold in many countries outside of the North American continent.

On a recent trip to Europe I had to go to Holland to check up on the ability of our combines to handle the long, tough straw commonly grown on the reclaimed Zuyder Zee farms, and I found that further provision had to be made to make the combine take this extra long straw which was cut within four to five inches of the ground. This is just an illustration of what the designer must be prepared to meet.

Lighter Weights and Greater Capacity (in relation to width of cut). During recent years all combine manufacturers have increased the capacity of their machines and reduced their total weight in relation to width of cut. However, this field is wide open for further improvement, and there is room for considerable betterment over anything on the market today. This is one item that must receive very careful consideration by all designers.

Total Variation of Tractor Speeds. We feel that, cover-



This picture shows four Massey-Harris combines harvesting from the standing grain

ing the field from heavy rice in California to normal grain on the plains, working speeds from ½ to 5½ mph would be ideal, and a road speed of 7 mph should be sufficient for transportation purposes.

We recognize that this road speed will be used in the field. Therefore, in our opinion no speed should be provided in excess of 7 mph, because a farmer will use it for threshing if available, to the detriment of machine capacity and traction horsepower requirements.

We find that custom operators tend to race their machines at excessive speed. It is difficult to hold them back when they encounter easy going. One operator told me that the rough ground was the only thing that was keeping him down to 7 mph. It was too rough to ride on the seat above this speed.

Sufficient Engine Power (to take care of difficult ground conditions as well as to operate the combine mechanism). The traction power required for any given size of combine has been carefully observed and we have arrived at the following conclusions: Power required to propel different sizes and models of machines does not vary in direct proportion to their weight and width of cut. We have found that on normal dry, level ground the power requirements for traction is from 8 to 15 hp. In conditions such as hilly land, light sandy soil, loose earth, or wet boggy ground, power requirements can go up to 45 hp and even more. The same will apply in the rice fields. We have found that wheel sizes play a very important part in traction horsepower requirements. A large diameter wheel with large cross-section tires takes less power to propel than the smaller type now commonly used. Tracks take less power than wheels where tracks are necessary, and, in states where the rice grows on the borders and it is necessary to cross borders, tracks require much less power to propel the machine than any size or type of wheel. However, in all of the above, price must be taken into consideration as well as some general standardization of design in wheel sizes. Here again it will be up to each individual designer to decide what size and type of wheel and what variations are to be used on a given machine.

POWER FOR THRESHING AND CUTTING MECHANISM

Power to operate the threshing and cutting mechanism varies more nearly in proportion to the width of cut. A 16-ft cut will require up to 40 hp. One item in horsepower requirements that must be kept in mind is that all drives must be designed with ability to stall the engine when the combine is forced beyond its capacity. This applies principally to the final cylinder drive, and, of course, does not necessarily apply to the traction drive, although when the traction is forced up to capacity, the operator will be given plenty of warning by the sound of the engine.

Weight Distribution in Relation to Wheels. One of the very important mechanical items to be overcome is to get the weight of the machine reasonably well balanced between all wheels. The added weight in the grain tank or bagger attachments must be kept in mind in weight distribution. The weight on the steering wheels should be sufficient for good control, and not be an excessive drag on the traction. This can vary slightly as the tank is filled with grain or as bags are carried on the bag chute. This weight distribution is a very important one and should be given a great deal of thought by all designers.

Attachments, Drives, and Straw-Handling Equipment. To suit variable crop conditions and different varieties of grain, various attachments are required, all presenting some problems in design.

The pickup reel is perhaps one of the greatest aids ever developed in helping harvest down, tangled, and difficult crops. This development has been left largely in the hands of small firms in different places. All these designs leave something to be desired, particularly in damp or badly twisted grain. There is an open field for designers to make a more practical and more satisfactory pickup reel than any yet in use.

While steel roller chains and both flat and V-belt drives are commonly used, there is still a field for improvement, both from the standpoint of variables, longer life and general efficiency, and plenty of room to simplify various drives. Farmers are looking for clean outside designs like the motor car and some of the more modern household appliances.

A problem has been presented by countries that want to save all the straw behind the combine. This straw is required for various purposes. The introduction of self-propelled combines may be held back in some countries until suitable straw-saving attachments are provided. The problem can be met in part by pickup balers, pickup straw presses, and bundle presses or trussers. No one of the above is the complete answer. What we believe is actually required is a semimounted attachment designed to make a tight or loose bundle, depending on the condition of the straw. In some countries farmers claim that the straw is drier coming from the combine than it will be at any future time.

Traction Equipment for Rice Fields. The problem to be met here is to have a combine that will propel itself under all and every type of rice field conditions. The steel crawler tracks commonly used will do the job very successfully from a traction standpoint, but they present a wear problem in sandy soil, and a road transport problem. This latter problem has been solved by individual large operators owning suitable transport trucks. The combine can be driven on to these trucks and unloaded at its destination in a few minutes. In territories where ground conditions are not always bad, large diameter spade-grip rice tires can be used with reasonable success, and they are very suitable for transport requirements.

The main difficulty encountered with wheels, where they can be used, is where machines have to cross borders to suit the local harvesting conditions. It is our opinion that the answer to all of these problems is a rubber pad track with provision to care for pin and bushing wear in place of the steel one commonly used. The rubber manufacturers, while keenly interested in this development, will never be in the price class unless this type of track finds more general use in other farm applications. However, this particular item should be followed actively by all designers. It is unquestionably true that rubber tracks would be used in many fields today where big diameter tires or dual tires are necessary if the price of the rubber tracks could be brought more into line with the price of large diameter wheels.

There is a big opening for rubber tracks and this field should not be overlooked by tractor designers.

Time has permitted me to outline only in a very general way the problems of design and to touch the highlights of this major development in the agricultural implement field, the development which has possibly made the greatest contribution to cost-reduction in grain harvesting of anything that has ever been introduced.

It is a development that has been recognized by leading agricultural equipment engineers, not only on the North American continent, but also to a lesser degree in Latin-America and in Europe, so that today a number of the major implement manufacturers are producing a line of self-propelled combines, and from latest information this includes Russia.

For the future further advancement and refinement challenge the genius of research specialists and engineers.

Discussion by S. C. Heth

I HAVE found that the problems involved in engineering self-propelled combines have been and still are very fascinating. So fascinating, in fact, that I cannot help but wonder whether the sheer pleasure of developing such machines, on one hand, and the novelty of operating them on the other hand, hasn't carried this type of farm implement beyond its proper economic position in the equipment industry and on the farm.

There is no question as to the desirability as well as sound economics of the self-propelled combine in irrigated crops where there exists a problem of following checks and borders and eliminating all but a relatively small number of border and ditch "jumps". This may apply to fields where contour farming is practiced. For other uses, however, I cannot help

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but question the economic soundness of the self-propelled combine.

If harvested at the right time, actual loss due to opening up a field is very small. In many sections, where there are liberal headlands, or where strip farming is practiced, the loss due to "opening" is zero. In windrow work, there is no sound reason for any difference in grain loss between the self-propelled and pull-type combines.

Regarding the man-power requirements of self-propelled and pull-type combine operation, I haven't found any difference. Both are properly one-man jobs when power-control headers are used. As far as safe and efficient operation is concerned, it is my opinion that it is much easier for an operator on a tractor to properly control the cutter bar height, and to see and avoid obstructions such as rocks, etc., than it is for a man on a self-propelled combine operator's platform. Certainly the view of the cutter bar itself is better from the tractor seat than it is from the platform of a self-propelled combine, where a man must observe this vital operating part by looking through a rotating reel and usually in a cloud of dust.

Considering the convenience of machine observation, for the operator, there are some arguments in favor of the self-propelled combine. I personally do not believe these arguments will "hold water". A combine operator, between steering, watching for obstructions, controlling proper cutter bar height, forward speeds, and taking care of turns, has his hands full and his eyes occupied. Outside of noting whether the grain is flowing out of the elevator spout, and whether there is an even flow of material out of the rear of the machine, the operator relies largely on his ears to detect anything out of order, and with a muffled engine on the tractor, this can be done just as well from in front of as from on top of a combine.

ADVANTAGES COMPARED OF TWO TYPES OF COMBINES

A pull-type machine is necessarily wider than a self-propelled unit of the same size cut. However, in the areas where large machines are generally used, transport widths are generally not critical and the slight difference in widths between the modern auger-type pull combines and the self-propelled type is of negligible importance. This comment does not apply to the long-distance custom operator, but it is my personal opinion that this type of operator is a war baby and will, generally speaking, join the Dodo when the machinery supply catches up with the demand.

In the areas where smaller farms are the rule, the arguments from the field opening and narrow transport width viewpoints become stronger in favor of the self-propelled combine. Inversely, the economic picture of the self-propelled combine becomes weaker. A self-propelled unit is, in effect, a combine mounted on a tractor. The smaller the combine, the larger the proportion of cost of self-propelled mechanism.

The well-arranged, small pull-type combine can be taken into and out of most grain fields without excessive difficulty. The proof of this is that they have been and are doing so. Such being the case, the arguments become largely a matter of grain loss in opening fields, and this is a very debatable point.

If the price, to the grain grower, of the self-propelled combine were just a small percentage over that of a pull-type combine, the economic picture would favor the self-propelled unit. As long as the price of the self-propelled combine is close to the price of a pull machine plus a tractor, I cannot help but believe the future market for self-propelled combines is relatively small.

On the sujbect of self-propelled windrowers and corn pickers, I can only say that these machines adapt themselves very well to tractor mounting and the idea of making them self-propelled or of providing a special self-propelled chassis is, in my opinion, economically unsound, and certainly unnecessary when we have so many fine general-purpose tractors available.

I hope I'm just a little wrong in all this, because engineering and testing self-propelled machines is fun and I love it. However, whenever I do my wee bit towards advancing modern science via the self-propelled idea, I wonder if I'm like the gentleman in the asylum when the visitor asked, "What brought you here?" "Modern science", the little man replied; "they asked me if I was Napoleon, and I said, 'Certainly not', and I would have fooled them except that they were using a lie detector on me at the time and the damned thing proved I was lying."

Discussion by C. J. Scranton

WE HAVE enjoyed and appreciated the paper presented by Mr. Carroll covering the basic requirements to be met in the design and development of self-propelled combines, and also the paper by Mr. Barger covering performance and some of the limitations of self-propelled equipment.

There are probably some cases where the self-propelled implement may be the ideal, and this seems to work out in the case of the small windrower. It is most difficult to make this unit in a small pull-type machine and develop the proper coordination with the present tricycle or general-purpose tractor so that the windrow can be laid on the stubble for satisfactory curing and at the same time be clear of all the tractor wheel tracks.

The self-propelled combine has now been produced in fair numbers. Corn pickers of this type are available, and the principle has also been applied to rakes, windrowers, and other tools. There is some romance in the idea of having any unit self-contained and ready to go when you step on the starter, but you must be able to afford romance.

It seems to us there are several pertinent reasons why self-propelled farm tools, in their present state of development, are either limited in their use to large or custom operations, to the handling of special crops, or to the meeting of very special conditions. This is somewhat borne out by the latest available production figures which are for the year 1946. These figures show, in the case of the combine, a sale of 2700 self-propelled units against a total production of 49,000 for all pulled-type machines.

These self-propelled units sold to the farmer through a price range of about $2,400 for the 7-ft cut to well over $5,000 for the larger special machines, and in anything approaching a normal farm economy these costs would deny the advantage of home ownership to the large majority of medium or smaller size farmers. This investment is as much or more than a standard farm tractor of sufficient power for operations plus a pulled harvesting machine of equivalent size and equipped with an engine. This same reasoning may be applied to self-propelled equipment of any type.

The modern tractor is the efficient mechanical draft horse of the farm, and may be obtained in the right size necessary to fit a variety of farm sizes and operations. Into these tractors are built engine power, transmissions to give a satisfactory range of ground speeds for the work to be done, and tire capacity to give the necessary tractive effort or to carry mounted implements. This tractor is designed to operate 365 days a year if necessary, and to pull or mount a wide variety of farm tools. It is a self-propelled power unit.

SELF-PROPELLED UNIT DUPLICATES TRACTOR

Self-propelled equipment, in its present development, duplicates many of the functional units of the tractor. The engine must have sufficient reserve power to propel the machine when ground conditions are bad as well as to operate the mechanism, when the crop is heavy the transmission must have a rather broad speed range, and the tires must be adequate to handle the heavier weights imposed or to give the necessary traction in the toughest conditions. This means a rather large investment in a machine which may be called on to operate only 90 days or less per year.

Self-propelled equipment depends on one engine for both field travel and power. This is true of any power take-off tool operated directly from the tractor, but the over-all cost is in favor of the latter. A standard machine pulled by a tractor and equipped with engine for threshing or functioning units only, maintains the right operating speed regardless of

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field conditions or ground travel. Unless the self-propelled mechanisms are overpowered for normal operations, the speed must be reduced to a crawl for soft ground or rough field conditions or poor work may be the result because less power is available for the threshing mechanism.

In the self-propelled machines it has been necessary to combine the power unit, the transmission gearing, and the crop mechanisms in one complete group. This has been no easy matter because cutting, shelling, separating, cleaning, storage, and other units are bulky and the welding together with power and transmission has resulted in a considerable sacrifice of accessibility and balance. Certainly the present self-propelled equipment is not as easy to service as the tractor or implement when not in combination.

There is a challenge in the self-propelled idea. Perhaps the answer is the development of a rearranged type of mobile power plant to replace the present tractor to which all reasonably sized farm tools may be quickly applied. We should be able to drive in and connect to these tools with little more difficulty than we tie up a shop truck with a tote box. This arrangement would seem to present the best over-all possibility for holding or lowering the over-all cost of farm equipment.

Some of us remember the days not too long ago when wheat, corn, soybeans, and other crops brought a fraction of what they do today, and when we listened to a great deal of talk about farm surpluses. Perhaps these days may come again. Let us think in terms of equipment our farmers can well afford.

Discussion by D. C. Heitshu

THE topic under discussion — "Should It be Self-Propelled?" — is a most interesting and intriguing question. We find this idea of self-propelling running rampant throughout the farming sections of the country. In view of this extreme interest it is a suitable time for us to endeavor to answer this question.

If we are to answer it, our first need is a definite understanding of the term "self-propelled". I will offer the following definition: An efficient integral power unit and implement under operating control of one man.

The foregoing definition immediately points to the fact that the all-purpose tractor and its mounted implements are self-propelled units. There is another way to look at it: the all-purpose tractor of the row-crop type has made us familiar with self-propelled implements, and now we are endeavoring to expand the principle first brought into actual and practical farm use with the row-crop type of tractor. The use of and experience with the row-crop type of tractor has sold the self-propelling principle to the farmer because it offers three outstanding general advantages:

1 A compact unit

2 A highly maneuverable unit

3 A general reduction of crop losses, crop damages, etc., through more timely and easier operation.

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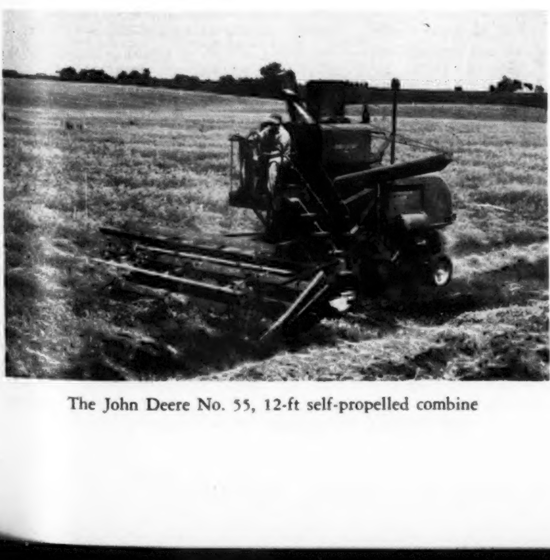

The John Deere No. 55, 12-ft self-propelled combine

Let us now return and endeavor to answer the question, "Should it be self-propelled?" I believe that the answer to this question can be broken down into three general categories:

1 All implements that attach quickly and easily to the all-purpose tractor should be so used, and are, therefore, self-propelled. The possibilities of this field have not been explored fully and more work can be done in the design of tractors and implements to improve their attaching and detaching, as well as their control and performance.

2 Implements which do not lend themselves to mounting on general-purpose tractors should be self-propelled, provided the unit does one or more of the following: (a) Saves labor; (b) efficiently supplants basic tractor power required to operate the farm, or (c) permits operation over bad terrain or under conditions where a separate implement and tractor combination cannot be operated satisfactorily.

A good example of the application of the foregoing points is the case of the self-propelled combine on the large wheat farm. Points (a) and (b) are active because the self-propelled combine saves labor through its easy and convenient operation. This is not an appreciable amount of labor as the newer one-man pull combines are easily handled by a single operator. However, the chances are that during a full season the single unit will prove to be more efficient so far as labor is concerned. At the same time the self-propelled wheat combine is of value to the farmer because it releases basic tractor power at a time when it can be used to advantage. For many years our soil technicians have told the wheat farmer that he should plow as soon as possible after the grain is harvested. The self-propelled combine makes this practice possible without overpowering the farm. The third point is well illustrated by the use of the self-propelled combine in the rice fields. Drawn combines have never been very successful in the rice harvest. However, the self-propelled unit can and does go through the worst possible conditions to harvest this crop satisfactorily.

2 Any individual self-propelled unit that can show a profit for the farmer is logical and should be considered as a commercial possibility. The profit which a self-propelled unit can return to the farmer is measured by (a) the labor saved, and (b) the increased return resulting from the use of added power.

These savings must be balanced against interest, depreciation, upkeep, and overhead computed on a reasonable life for the machine, which should not exceed ten years. In figuring the profit that a machine can make for the farmer we should not spread the profit-making period over too many years. Technical advances, changes in economic conditions, and similar factors are not sufficiently stable to justify our assuming that the farmer can take 12 or 15 years to pay for an investment involving a single machine.

The real answer to "Shall it be self-propelled?" apparently lies in a true, all-purpose farm power unit. The present-day individual self-propelled units point the way in some of the features required in the all-purpose farm power unit. In addition to those features outlined by Mr. Carroll — accessibility, weight distribution, ample power, sufficient flotation, etc. — I would like to suggest the following features as definite requirements needed in the suggested unit:

1 Direct engine-drive power take-off. It is very likely that several outlets should be available on this power unit, instead of a single one as on present tractors.

2 Infinitely variable transmission drive.

3 Fore and aft operation.

4 Variable operator's position.

5 Extremely compact and/or fully adjustable as to tread, engine location, height, etc., so that the unit would be capable of fitting into any available open space in or about the implement to be driven.

With these brief specifications I leave you with the question, Who is going to solve this problem?

Engineering-Management Aspects of Self-Propelled Farm Machines

By E. L. Barger
MEMBER A.S.A.E.

TO BE accepted generally the self-propelled machine must show economic advantages. Operational advantages will bear weight, but ultimately the self-propelled machine must pay off in dollars and cents. Advantages such as convenience, flexibility, portability, etc., alone do not make a machine a sound farm production unit or investment unless they provide better economy of production. This paper is based on the use of self-propelled machines in farming operations on about 1500 acres of Iowa State College land and upon engineering and economic principles that must be considered in good management practices.

A precedent for independent drive was set several years ago when industrial shop machinery changed from lineshaft drives to independent electric motors. There were those who argued against the high cost of independent drives. Experience proved them to be highly desirable and the production of cheaper and better electric motors plus their many operational advantages in direct drives soon made their use sound production economy. It must be remembered in analyzing this problem, however, that industrial machines and agricultural machines have entirely different use factors. The industrial machine may be used every day of the year. The agricultural machine, due to the seasonal nature of crop production, is limited to a pitifully small number of days or hours per year. The average farm machine exclusive of tractors, trucks and wagons is used only about 12.5 days per year*. The combine is seldom used over 20 days per year. The corn picker is also seldom used over 20 days per year.

There are important factors favoring the use of independent power units on agricultural machines. Engine power has become cheaper. The trend toward greater custom operation due to high cost and scarcity of machines and the high cost of labor favor the self-propel. Farmers are also becoming more interested in high performance, greater flexibility, and portability of farm machines. High prices for agricultural products permit farmers to invest in more costly machines.

It is a rather simple matter to make operating cost comparisons of different machines by making certain assumptions, by knowing certain performance factors, and by fixing certain variables. Such an analysis is of value to the manager. A series of operating cost comparisons have been prepared and are illustrated in Figs. 1 to 4, inclusive. Fig. 1 compares the cost per acre of harvesting small grain with a 7-ft, self-propelled combine and a 7-ft, pull-type, power-take-off-driven combine.

Basis of Operating Cost Calculations. The pull-type machine is powered with a 2 to 3-plow size tractor. The delivered price of the self-propelled combine is \$2625. The pull-type machine delivers for \$1250. The purchase price of the tractor is \$1575. A service life of both the self-propel and pull-type machines is assumed to be 2500 hr, and this is to be put on in 12½ years. The tractor is given a service life of 8800 hr put on in 11 years at 800 hr per year.

A capacity of two acres per hour is used. Our experience shows this to be an obtainable figure.

A fuel price of 17c per gal is used. The fuel consumption for the self-propel over two years of operation has been 1.7 gph (gallons per hour). The tractor fuel consumption is figured at 2 gph. The oil cost is 85c per gal, and the oil consumption including drains is figured at ½ gal per day in each case. Labor is figured at 90c per hr.

A repair rate is assumed equal on each machine at 3 per cent of the original cost per year. The tractor repairs are assumed to be 3½ per cent of the original cost per year. Interest on the investment is figured at 5 per cent per year on the average investment. Taxes, insurance, and housing are charged against the machines at 2 per cent of the first cost per year. Lubrication is figured at 1 per cent per year. The calculated base cost includes all fixed and operating costs for power and machinery and labor. In the case of the pull-type, power-take-off-driven machine, the tractor charges included are only for that proportion of the total 800 hr use that are represented by the combining operation.

Self-Propelled and Pull-Type Combines. At 50 acres per year the cost per acre with the self-propel in \$9 as against \$4.80 with the pull-type machine. At 100 acres per year this drops to \$4.80 with the self-propel and \$2.80 with the pull-

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*Fenton, F. C. and Barger, E. L. The cost of using farm machinery. Kansas Engineering Experiment Station Bulletin No. 45, 1945.

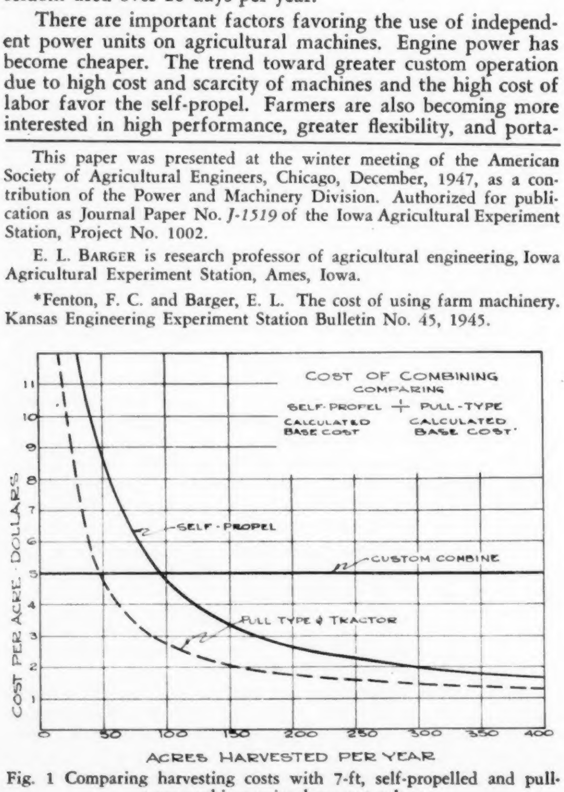

Fig. 1 Comparing harvesting costs with 7-ft, self-propelled and pull-type combines using base cost values

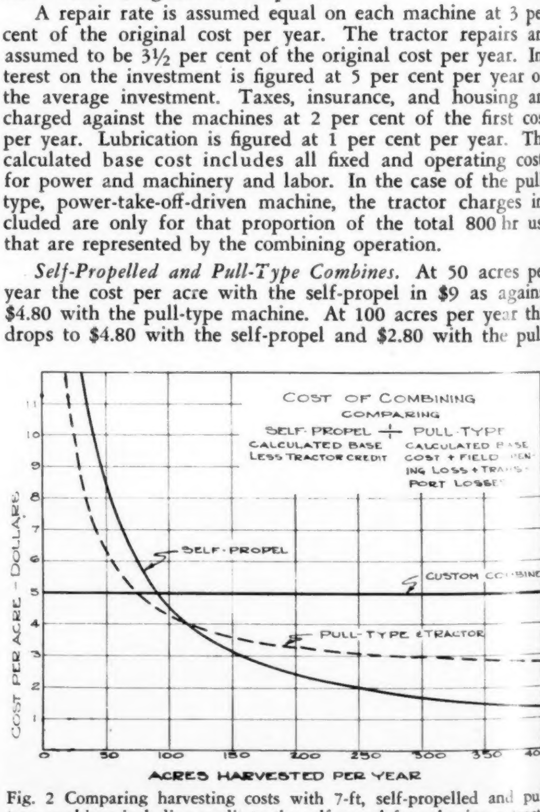

Fig. 2 Comparing harvesting costs with 7-ft, self-propelled and pull-type combines including credit to the self-propel for releasing a tractor and charging the pull-type for field opening losses

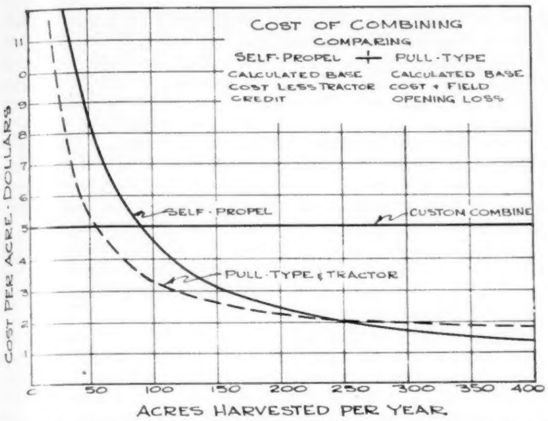

Fig. 3 Comparing harvesting costs including credit to the self-propel for releasing a tractor and charging the pull-type for both field opening losses and a sum representing inconvenience losses

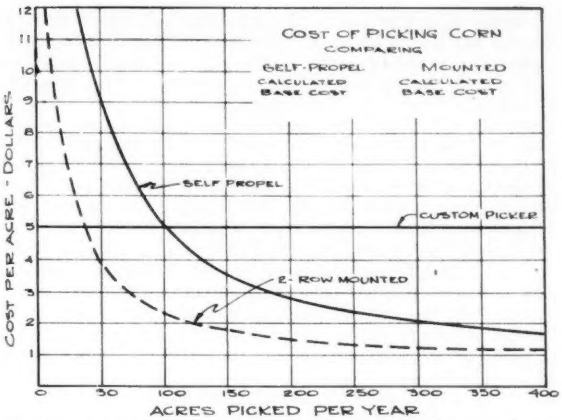

Fig. 4 Comparing picking costs with self-propelled and mounted corn pickers representing base costs only

type combine. At 300 acres per year, which approaches a pretty good year's work for machines of this size, the self-propel is down to $2.00 per acre and the pull-type to $1.50.

In these comparisons it is assumed that the efficiency of the two machines in saving grain are equal and our tests have indicated that there is no justification in assuming otherwise. They do not consider, however, the factor of field opening losses, nor do they give the self-propelled machine any credit for releasing a tractor on the farm during the harvesting period. Also there is a convenience factor that should be considered and will be taken up later.

During the summer harvesting period on most farms, there is a need for more tractor capacity in cultivating and hay work. In our operations it has been of some value to have the regular tractors used in farm work free during the small grain harvesting season. For this reason it seems logical that one might credit the self-propel with something to represent the value of the tractor which has been released during the harvesting period. Fig. 2 compares the two machines with the self-propelled combine curve adjusted for this credit. The credit made is 50c per hr which very closely represents the fixed costs of a medium-sized tractor and this, since a two-acre-per-hour capacity is used, equals 25c per acre credit to the self-propel.

Also in like manner any other advantages of one machine over the other should be recognized in the comparison and something to represent field opening losses should be included. In this analysis a field of forty acres and square in shape is used. Our studies have not gone far enough to state with a great degree of accuracy what the field opening loss is, but it appears that not more than 50 per cent of the crop in the opening or back swath is lost. I am assuming, then, a 40-acre field, a 50 per cent loss in back swath, a 50-bu yield, and a dollar per bushel grain price. This is chosen because it can be transposed from a 50-bu yield at $1 per bushel to a 25-bu yield at $2 per bushel, or a 16⅔-bu yield at $3 per bushel.

TABLE 1. COMPARISON OF CALCULATED COSTS IN DOLLARS PER ACRE OF HARVESTING WITH SELF-PROPELLED AND PULL-TYPE COMBINES AND SELF-PROPELLED AND MOUNTED CORN PICKERS*

	Combine					Corn picker	
	Self-propelled		Pull-type			Self-propelled	Mounted
Acres per year	Base costs	Base costs less tractor credit	Base costs	Base costs and field opening loss	Base costs and field opening and transport losses	Base costs	Base costs
20	21.55	21.30	10.80	11.30	12.30	23.00	8.45
50	9.00	8.75	4.80	5.30	6.30	9.55	3.85
100	4.80	4.55	2.80	3.30	4.30	5.10	2.35
150	3.40	3.15	2.15	2.65	3.65	3.60	1.85
200	2.70	2.45	1.80	2.30	3.30	2.85	1.60
250	2.30	2.05	1.60	2.10	3.10	2.40	1.40
300	2.00	1.75	1.50	2.00	3.00	2.10	1.30
350	1.80	1.55	1.40	1.90	2.90	1.90	1.25
400	1.65	1.40	1.30	1.80	2.80	1.75	1.20

*See discussion in text for basis of calculations.

In other words, it applies within a reasonable degree of accuracy with oats, or other small grains. A 7-ft swath around a square 40-acre field is equal to 0.84 acre. On this basis, the opening losses are equal to 50c per acre. Fig. 2 compares the two combines with the self-propel credited for 25c per acre for the tractor that has been made available for other work, and the pull-type combine has been debited 50c an acre representing the field losses it would have caused.

It might be pointed out here, however, that we have not found, on the average, that our opening cut would be equal to a trip completely around a square 40-acre field. It should be recognized, however, that it might be greater or less depending upon the size of the field and the crop rotations followed. On smaller fields it would be greater. In strip cropping practices, it might be considerably greater. Our experience has been that we have incurred losses only about half way around the field. In other words, there are frequently roads or lanes and in normal crop rotation practices fields are frequently bordered by hay land, and at the small grain harvesting season hay has been removed and it is not necessary to knock down grain completely around the field.

We have made the full assessment in this case, however. It might be added at this point also that without the benefits of self-propelled windrowers we are not having the full gain from reduced field opening losses in a farming area such as Iowa. The matter of self-propelled windrowing will be mentioned later. The costs are about equal in this comparison at 250 acres per year. At 100 acres per year the per acre costs are $4.55 and $3.30 for the self-propel and pull-type, respectively.

There is another factor that might be of considerable consequence in the problem. It is extremely difficult to evaluate such things as convenience and portability. We must recognize then that any values assessed are purely speculative. Fig. 3 compares the self-propelled machine with a tractor credit deducted from the base cost and the pull-type power take-off machine charged for field opening losses and also a sum that we will call transport loss.

For example, we have one half-section farm made up of 1, 2, 4, and 6-acre lots. This is a swine breeding farm and all of these small fields are fenced hog tight and most of the gates are 12 ft wide and open from 20 and 30-ft lanes. These small fields are farmed in a rotation where livestock is on the land one year out of three. To establish grass and legumes, oats are grown as a nurse crop. We can get our pull-type combines into these fields by backing them through the gates, and of course the inconvenience of handling equipment under such a setup can well be imagined. On this one farm we find a situation where the flexibility and portability of the self-propel can be of considerable importance.

Other special situations that exist on other farms that favor the self-propel could be mentioned. In Fig. 3 another adjustment is made by assessing the pull-type machine $1 per acre to cover the losses incurred in transporting. This is mostly a time and labor loss. Obviously this is too much for some cases, but will satisfy for this discussion. This causes the cost lines to cross at 130 acres at which a $4.00 per acre cost is reached. At 200 acres the cost is $2.45 for the self-propelled as against $3.30 per acre for the pull-type machine. Other combinations of circumstances and values could be used and somewhat different results would be obtained.

The straight line represents a custom combine rate of $5 per acre. This is indicated only to show where and when a person might consider custom operation as against owning either of the types of machines under discussion.

Self-Propelled and Mounted Corn Pickers. A fourth cost comparison is made of picking corn with a self-propelled picker and a two-row mounted picker. The basis for calculations in this case are as follows: The delivered price of a two-row, self-propelled picker is $2700. The two-row mounted picker is $900. The tractor is the same one used in the combine comparison. The service life of the two pickers is assumed equal at 11 years, or 2200 hr. Fuel consumption is figured the same as the combine, and labor is taken at the same figure. These two machines are compared on a base cost only. Since the field opening problem would be identical with these two, there is no justification in charging or crediting either one for this item. The transporting problem is quite similar with the two, and there seems no reasonable justification for making any allowance on either. The capacities of the two are assumed to be equal. No credit has been made in favor of the self-propel for releasing a tractor during the picking period, although this could be justified and if so would reduce the cost per acre with the self-propel by 25c. The mounted picker might also be charged for labor cost for mounting and demounting. This has cost us 25c per acre of corn picked in our operations. If 100 acres are picked per year, the costs are $5.10 and $2.35 for the self-propel and mounted, respectively. At 200 acres there is an even dollar per acre in favor of the mounted. If tractor credit is allowed and mounting time considered, the lines just about meet at the 400-acre-per-year point. It is recognized in this comparison that an extreme case is being used. Nevertheless it is the type of comparison that must be considered from the management angle.

Self-Propelled Windrowers Needed. To obtain the full benefits of self-propelled combines in the Midwest, we must have self-propelled windrowers that lay the windrow within the cut. At the present time it is estimated that 65 per cent of the oat crop in Iowa is harvested by the windrow method. Much of this is being done with old grain binders. Commercial windrowers of a pull-type that deliver the cut grain at the end of the machine are no better as far as the self-propelled combine is concerned.

Fig. 5 illustrates a self-propelled windrower built by Harold Folkerts. He has used this machine one season harvesting 100 acres and opening fields for his neighbors. It is powered with a 9-hp, single-cylinder engine and has a 9-ft cutter bar. Mr. Folkerts uses only 7 to 8 ft of the cutter bar width except on corners. He intentionally made the machine wider than needed so that he could turn rounding corners without leaving any standing grain on the turns. It uses a double-platform canvas and the windrow is placed within the cut swath. He is able to cut clean corners and by having the rear wheel offset it does not run over the windrow. Iowa State College has under way a project for the design and construction of a mounted windrower that will be operated on the rear of a tractor. It will discharge the windrow within the cutting width and we hope will combine the advantages of a mounted machine as well as the self-propel feature of cutting and placing the windrow within the swath harvested.

Harvesting Soybeans with a Self-Propelled Machine. In Iowa the self-propelled combine must handle both small grains and soybeans. At best cutter bar losses are high in harvesting soybeans, and the only answer to this at the present time is to cut the beans as low to the ground as possible. Perhaps in the future crop breeders will produce a bean that produces pods higher on the plant stem. Some advancements have been made in this direction, but at the present time the design of the combine cannot count much on such a soybean development. The cantilever system of mounting the cutter bar and platform in front of the main wheels of the self-propel creates a problem in harvesting beans. Frequently the ground is soft in varying degrees and the wheels will mash in at irregular depths causing the cutter bar to dig in or cut too high. Problems caused by ridging during cultivation make it extremely difficult to keep the cutter bar at a uniformly low cut position. Of course, these problems are not at all absent in the case of the pull-type machine. The operator fatigue in trying to maintain a uniform low cut with the self-propel has been rather critical. One solution to the problem may be to equip the cutter bar with either runners or low rubber wheels so the cutting mechanism can be placed down in contact with the soil and allowed to float with the unevenness of the surface. Something different in the way of a height control will be needed.

The problem of training operators to handle self-propelled machines satisfactorily is not serious. The problem seems to be a little greater than that of handling a pull-type machine and a tractor. In general, after the operator becomes accustomed to the machine, he prefers it to the pull-type combination.

In conclusion, the following points are proposed as influencing factors that will assure the self-propel a place in the corn belt states:

1 Hold the cost ratio between the self-propelled machine and the mounted or pull-type machine to the smallest possible value.

2 Continue thinking and efforts toward the development of a common power unit and carrier frame that will permit interchangeability of two or more machines — possibly combines, forage harvesters, balers, corn pickers, and others.

(Continued on page 111)

Fig. 5 *(Left)* A self-propelled windrower which lays the windrow within the cut swath • Fig. 6 *(Right)* The self-propelled combine in Iowa must handle the small grains — much of it windrowed — and soybeans as well

Engineering Phases of Curing Bright Leaf Tobacco

By O. A. Brown and N. W. Weldon
MEMBER A.S.A.E.

TOBACCO has been an important agricultural cash crop of the southeastern part of the United States since colonial days. The first record of export from the English colonies was in 1618 when 20,000 lb of tobacco were exported from Virginia. Ever since then tobacco has taken an increasingly important part in both domestic and foreign commerce and has been a source of substantial internal revenue to the federal government and to many of the states.

The flue-cured tobacco production in the United States in 1946 was estimated at 1,352,024,000 lb and had a market value of $653,418,000. The federal government receipts from taxes on tobacco products in 1946 amounted to $1,165,519,000. Of this amount cigarettes brought a revenue of $1,072,971,000. Amounts received by labor, manufacturers, and dealers cannot be estimated, but the income from tobacco makes it one of the important agricultural crops of the United States. The cigarette has become the leader of all tobacco products and flue-cured tobacco is the base of a modern manufactured cigarette.

The most important products made from tobacco are cigarettes, chewing tobacco, snuff, and cigars. Fig. 1 shows the relative amounts of tobacco in these products and the flue-cured tobacco produced for the periods from 1911 to 1945. From 1885 to 1945 the number of cigarettes increased from 1,000,000,000 to 332,232,000,000. Most cigarettes are made from blended tobaccos. The domestic tobaccos usually used in them are flue-cured, Burley and Maryland. Turkish tobaccos are also used in the blends. The proportions of the domestic types used in the blends are approximately the following: flue-cured, 53 per cent; Burley, 33 per cent; Maryland, 4 per cent. About half of the tobacco in a cigarette is flue-cured tobacco.

The term "flue-cured" tobacco is derived from the method of curing the leaf. In the latter half of the nineteenth century tobacco growers were experimenting with methods of curing to a bright lemon color tobaccos grown on the light sandy soils of the Southeast. It was first cured with open charcoal fires and later by a system of metal flues through which the flames and gases from a wood fire were passed. The tobacco growers worked out a method of procedure which produced a bright lemon-colored tobacco that found a ready market both at home and in foreign countries. The early barns for curing bright leaf tobacco were built of logs and were approximately 16 ft square and from 12 to 16 ft high. They were heated by means of sheet-iron flues connected to furnaces built of rock. The furnaces, usually built near each of two corners on the same side of the barn, extended into the barn and were long enough to burn long poles or split wood. Some of the early barns with their heating systems are still in existence. Fig. 2 shows a barn of the very early type with its heating system.

The shapes of the barns and the methods of heating them did not change much, but lumber and other materials were used for construction. Fig. 3 shows a barn and its heating system built in 1946. Except for the flue arrangement, there is little difference in the construction from that of Fig. 2.

In some sections of the flue-cured tobacco area, very few barns are built of logs, and many of the barns are larger than the log barns. Fig. 4 shows a battery of barns used in eastern North Carolina. The sizes of barns vary from 16x16x12 ft to 22x22x19 ft high, outside dimensions. Some effort is being made to make 18x18x17 ft high the standard. Such a barn is known as a 4-room, 7-tier barn. The divisions are made by the tier poles on which the tobacco is hung. A 4-room, 7-tier barn will hold approximately 700 sticks of tobacco of 100 leaves for each stick. The number of leaves depends on their sizes and varies from year to year and from one section to another. Each stick of green tobacco weighs about 10 lb and the leaves contain between 85 and 90 per cent water.

Curing Process. The tobacco curing process consists of three steps, namely, yellowing the tobacco, killing and drying the leaf, killing and drying the stem. It is not correct to say that all the variation in quality of flue-cured tobacco is due to curing methods for the quality of tobacco is affected by many factors. Tobacco growers know that proper conditions in the tobacco-curing barn are very important, and that the conditions of curing have much to do with the price received for the tobacco. It is the purpose of this paper to make a preliminary report on some of the research which is being conducted by the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture, in cooperation with the North Carolina Agricultural Experiment Station and the North Carolina Department of Agriculture at its tobacco branch station located near Oxford, N. C., on curing bright leaf tobacco.

The engineering problem in curing bright leaf tobacco is one of getting heat to the tobacco leaves in a relatively dark building at a rate and under humidity conditions which will be most favorable to the correct physiological, chemical, and physical changes which take place in the leaves to produce a bright lemon-colored leaf which has the feel of a fine kid glove. To attempt to treat simultaneously 70,000 leaves in one barn with a rather crude heating and ventilating system is an undertaking which requires skill and experience. This, however, is what the tobacco growers have been doing with some degree of success for more than a half century.

The method is to place the tobacco in the barn, build a small fire, and maintain a temperature of approximately 90F (degrees Fahrenheit) during the yellowing period. During this period two factors are important, namely, (1) to give the physiological and chemical process an opportunity to convert large quan-

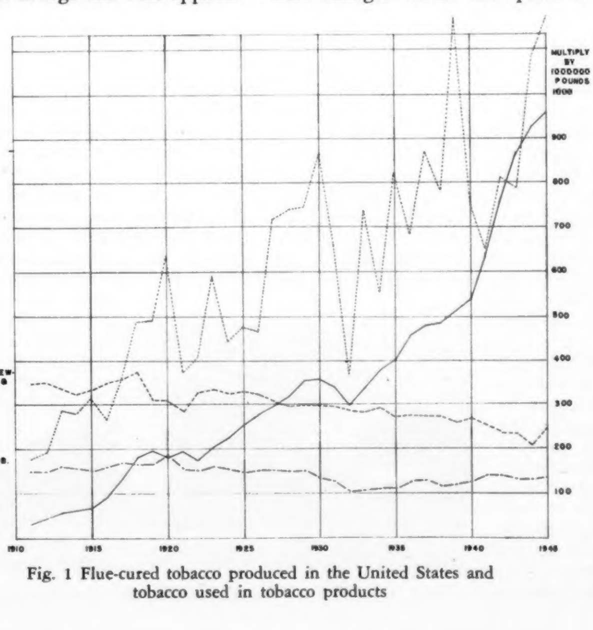

Fig. 1 Flue-cured tobacco produced in the United States and tobacco used in tobacco products

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a joint contribution of the Farm Structures and Rural Electric Divisions.

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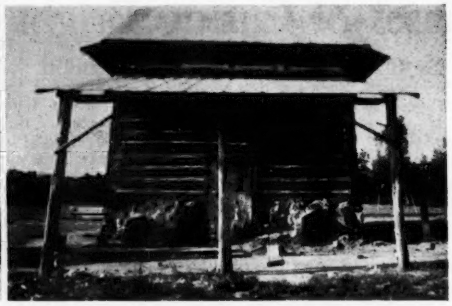

Fig. 2 *(Left)* This tobacco-curing barn near Roxboro, N. C., is built of logs which were first used about 75 years ago in a similar barn with the tierpoles for cut tobacco. Later the barn was torn down and rebuilt for primed tobacco • Fig. 3 *(Right)* This barn was built in 1946 and shows but little change from the one shown in Fig. 2, which is about 75 years older

tities of the starches to sugar and (2) to maintain a physical condition which will remove the moisture from the cells as fast as the physiological and chemical processes of converting starches to sugar progress.

Killing the cells of the leaf may be done in two ways—(1) by drying the cell or (2) by increasing the leaf temperature to the lethal temperature. If part of the cells are not killed by drying during the yellowing period, the water load becomes too great (at 120 to 135F) when the lethal temperature is reached, and an undesirable condition known as sweating may be developed. Sweating affects the quality of the tobacco by causing it to sponge. Sponging is the result of the temperature remaining too low because insufficient heat reaches the tobacco leaf.

With the present method of curing tobacco, heat is convected from the heating system to the tobacco leaves. The same gases which convect the heat from the heating system to the tobacco must also take the moisture given up from the leaf. This means that the atmosphere surrounding the leaves must never be saturated at a temperature equal to or higher than that of the leaf temperature. When heat flows from a saturated atmosphere to the leaf, "sweating" will take place. On the other hand, the higher the humidity of the atmosphere, the more heat can be carried by a unit volume of gas. To state this in another way, in the early stages of curing the air should pass through the tobacco at such a rate that it will be nearly saturated when it has passed the last tier of tobacco. The engineering problems of generating, distributing, and utilizing the heat efficiently are the ones under investigation.

The yellowing process in tobacco leaves is a progressive one. The leaf cells should be killed when the correct color is reached. The lamina of the leaf is the first to become yellow and the heavy part of the midrib is the last to yellow. One of the difficulties in curing bright leaf tobacco is to get the proper heat balance between the lamina and the midrib. At a low relative humidity, water in the midrib tends to keep the temperature below the lethal temperature by evaporation. If rapid drying is permitted, the midribs will dry green and cause the grade of the tobacco to be lowered since green tobacco is very undesirable. Experiments have shown that the cells in the stem can be killed at the same temperature as the cells in the lamina, if the same temperature can be maintained in all parts of the leaf. The problem of maintaining a uniform temperature throughout the leaf is one of getting a sufficient quantity of heat to the midrib to maintain its temperature the same as the lamina temperature. Only a small quantity of heat is used for the yellowing period. When the lethal temperature of the cells is reached, the rate of heat generation must be much greater to evaporate the water released and to maintain a given temperature. Growers usually kill the midrib cells by increasing the temperature in the barns to as much as 200F. Experiments conducted last year indicate that, if a relatively high humidity is maintained throughout the curing process, the midribs can be killed at lower temperatures than are usually used.

The present flue system of heating tobacco barns is inherently an inefficient one. Round flues 10 or 12 in in diameter are used. Both larger and smaller flues have been tried, but since the surface area of the flues varies as the diameter and the cross section varies as the square of the diameter, the larger flues give an excessive stack loss. The smaller flues do not have enough radiating surface without too great a length. Since rectangular flues can have the surface and cross section varied independently, such flues are being tested this year.

As long as wood was used with sheet-iron flues, there was but little trouble with corrosion. With the introduction of coal and coal stokers, the life of the flues became very short. Attempts are being made to find material from which flues can be made, so that they will last for the life of a barn. Transite and aluminum will be used in tests this year. If the rectangular flues prove successful, there is no reason why flues could not be made of copper or other materials.

Flues are used with wood, oil, and coal for heating tobacco barns. Approximately 250 sq ft of sheet iron is required for each set of flues. There is no reason why other heating systems cannot be used for curing tobacco and many variations from flues are being made.

The open flame burner and the stove-type burner have both been introduced into tobacco curing and have been accepted by many tobacco growers. Propane gas has been used with an open burner shielded by a screen. Seven cures were made with gas heat at Oxford last year and some of the systems will be put out with tobacco growers this year. The stove-type, blue-flame, asbestos-wick oil burner has been used extensively for curing tobacco. The variations in oil burners are quite numerous and new ones are appearing on the market. The great variety of heating systems makes the problem of working out a uniform curing system for tobacco next to impossible. Even the flue arrangements cannot be uniform because of the various types of equipment on the market. An attempt is being made to establish an efficiency for tobacco barns so that better heating systems can be set up.

The ventilating system of a tobacco barn is next in importance to the heating system. The humidity in the barn must be kept below saturation after the tobacco begins to yellow. The most critical point is between 120 and 135F.

There are some special factors which make tobacco barn ventilation rather difficult. One of the most troublesome of these is the channeling of air currents through the tobacco. To place the tobacco in a barn so that the distribution is uniform is impossible. In most tobacco barns heated air rises through the open spaces more rapidly than through the more compact leaves. The heated air causes the tobacco leaves to

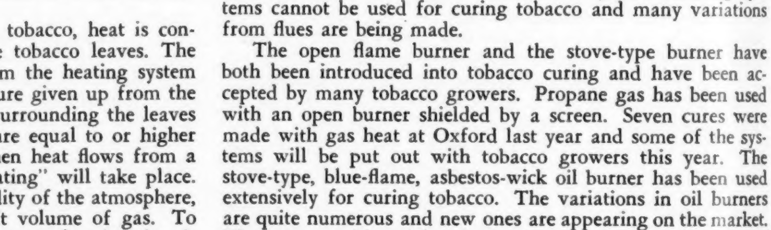

Fig. 4 This series of tobacco-curing barns are near Greenville, N. C.

"flop", thus increasing the sizes of the openings which cause more air to follow through the channel. Winds and poor heat insulation in a tobacco barn add to the difficulties of proper heat distribution and ventilation. The solution to the problem is to have the heat input, air input, and air output under control in a well-insulated barn.

Since the cross section of a tobacco barn is large, the ventilation seems to be better controlled with only slight air movement. Attempts to use fans for forced-air circulation have resulted in worse chimney or channeling effects and usually in longer periods for curing the tobacco and in greater fuel requirements.

During the yellowing period it is possible, with the proper ventilating system, to remove 20 or 30 per cent of the moisture from the leaves without affecting the coloring of the tobacco. Removal of moisture during the yellowing period greatly reduces the water load when the lethal temperature is reached, and is the best method of preventing sweating and sponging. When the tobacco has reached the desired color, the water must be removed from the leaves as rapidly as possible. This requires that the heating system have enough capacity to supply the heat of vaporization as fast as the water comes out from the leaf. The air which performs the two functions of carrying the heat to the leaves and of carrying the water away from them must move. The function of the ventilating system is to make possible the proper air movement and to control this movement of air in the barn.

Since the specific heat of liquid is greater than that of air and since it is easier to get a more uniform temperature distribution in liquid, it would seem quite possible to kill the cells of the tobacco leaves by dipping them either in water or some desirable chemical solution, or by heating them by more direct means of radiation. Some experimental work has been done using the method of dipping the leaves, and the results are very encouraging. The experiment, however, is in its preliminary state, and only few data are available on the quality of the tobacco.

FACTORS GOVERNING RATE OF DRYING

After the color has been fixed in the leaf, the tobacco can be dried as rapidly as is consistent with the economy of the unit without scorching the leaf. The moisture from the midrib must be reduced until the stem is brittle. This prevents mold growing in the tobacco after it is windrowed. When the cure is finished, the tobacco is ready to be "ordered" or brought into "case".

"Ordering" is the taking up of moisture by the tobacco leaves from the atmosphere. When tobacco is properly ordered, the leaf is pliable with a slight adhesive quality. If there is considerable moisture in the atmosphere, tobacco is easily ordered by putting out the fire in the tobacco barn and allowing cool air to circulate through the tobacco. If the humidity of the air is low, it is sometimes very difficult to bring the tobacco into order. This, however, is another engineering problem which needs some attention for its solution.

The new experimental tobacco barns at Oxford, N. C., are built as nearly alike as it is possible to make them. They have double walls of ¾-in planks with a layer of one-ply building paper between the planks. The outside barn dimensions are 18x18 ft with four rooms of seven tiers inside. The foundations are made of concrete blocks three tiers high. The second tier of blocks has the axis of the holes in the blocks in the horizontal plane. The barns are sheathed and covered with block-slate-coated, three-ply asphalt roofing. Two barns used in 1946 are heated with coal stokers. One new barn this year will be heated with wood and one with oil.

The coal furnaces are built of firebrick, are one brick thick, and are completely within the barn. The furnace walls are six firebricks long, four bricks wide and ten bricks high, outside dimensions. Four fireclay tile are used to cover a furnace. A piece of 14-gage sheet metal is placed over the furnace and extends over the fire joints and the cleanout door which is in the barn. The furnaces and flue arrangements in the two barns are alike.

Five tobacco cures were made in each of these two barns. The first cures were made with the two barns alike. No change was made in No. 1 barn throughout the season. No. 2 barn had four changes in the following order: Openings at the eaves were closed, draft controls were put on each of the flues where they come to the outside of the barn, the inside walls to the plate were covered with 2-in fireproofed cotton insulation, and the openings in the foundation were completely closed.

The cures in the two barns were started at the same time and kept as nearly as possible at the same temperatures. After each change the barns were filled with an equal number of sticks of tobacco which had been divided in the field stick by stick. The results are shown in Table 1.

TABLE 1

Barn No. 1: Coal used, lb	Barn No. 1: Time required, hr		Barn No. 2: Coal used, lb	Barn No. 2: Time required, hr
2434	115¾	first	2404	115½
No change			Eave ventilators closed	
2338	121½	second	2118	107¼
No change			Flue draft controls added	
2253½	125	third	1743	115 5/6
No change			Insulated 2 in cotton to square	
2399	119½	fourth	1545½	96¾
No change			Bottom ventilators closed	
1989	107 7/12	fifth	820	95 1/12

These data indicate the saving in fuel that is possible by having the correct barn construction, and the saving that might be effected in the 400,000 flue-curing tobacco barns. In addition to these savings growers might also expect to profit because of the better grade of the tobacco. It might also be pointed out that the barn with the least fuel consumption had a more uniform cure than the barn with the higher fuel consumption. The three things which accounted for the fuel saving were: (1) more even temperature throughout the barn, (2) better heat insulation, and (3) better control of the air flow through the tobacco. The preliminary research on tobacco curings indicates that farmers usually use more air than is necessary for curing tobacco. More efficient heat use and better tobacco can be obtained if the heating and ventilating systems are under complete control. This means that the heating unit must have sufficient heat capacity, external influences such as wind must be reduced to the minimum, and the gases must not be exhausted from the barn until they are carrying the maximum water load.

The furnace for the wood-burning barn is being designed by the engineers of the USDA Forest Products Laboratory and the barn temperature will be controlled by a thermostat. The gas heaters which will be used this year will have no furnace. The gas will burn in an open-flame-type burner with automatic temperature control. The oil burners will be of the flue type with thermostatic controls.

To bring to focus the magnitude of the engineering problems in the flue-curing tobacco industry in agriculture, let us consider the requirements: There are approximately 1½ billion pounds of cured tobacco sold on the markets; the green tobacco, therefore, weighs about 15 billion pounds, and this amount is handled on an average of 8 times by human hands in bundles of about ⅓ lb. This means that for 300,000,000,000 times a human hand has to grasp a bunch of tobacco or handle it on a stick. It is handled an equal number of times from the time it is cured until it is sold at the tobacco sale. Approximately 12,000,000,000 lb of water are evaporated from the annual crop. If all this water were evaporated by using coal in the present structures, it would require approximately 1,500,000 tons of coal.

Self-Propelled Farm Machines

(Continued from page 108)

3 Continue improvement in engines at lower cost for wider use as independent drives.

4 Make available self-propelled or mounted windrowers that place the windrow behind the cut swath.

5 Improve performance of present self-propelled combines to permit close and easier cutting on irregular ground surfaces.

Drying Seed Grain with Calcium Chloride

By J. W. Simons
MEMBER A.S.A.E.

INTEREST in seed and grain drying is increasing rapidly in the southeastern states. This is due primarily to the increased production of seed and grain crops and the fact that, since much of the harvesting is now done by combines, the moisture content of these products is generally higher than when cut by binders and allowed to dry before threshing. In the southern half of Georgia, the introduction of a new crop, blue lupine, has been one of the outstanding factors in bringing about the more widespread use of mechanical driers. Blue lupine seed often does not mature uniformly, resulting in an appreciable proportion of green seeds, so that some rapid drying method is needed in order to protect seed viability.

Most of the driers in South Georgia are operated in connection with commercial seed cleaning and grading plants or by farmers' cooperatives. These driers have capacities ranging from about 12 to 75 tons per 24 hr, with moisture content reductions of from about 2 to 20 per cent. Probably 6 to 8 per cent reduction would be a reasonable average. Eight hundred tons of blue lupine seed undoubtedly was the largest amount dried in any one plant in Georgia during the 1947 season. While these driers have been primarily of commercial size, definite interest has been indicated by individual farmers in average farm-size driers.

A few driers in the South utilize forced atmospheric air, but by far the majority provide supplemental heat, usually from burning butane or propane gas or fuel oil. Under the high temperature and humidity conditions existing in the Southeast, experience has shown that some supplemental heat or other drying agent is needed in order to obtain economical use of drier facilities and to reduce the long drying period otherwise required which often affects seed viability greatly. Since driers in Georgia have been used mainly for drying seed and grain for seed purposes, the protection of germination is of primary importance.

The use of supplemental heat, particularly for small farm installations, has several disadvantages, namely, (1) the temperature of the air must be carefully controlled in order to protect germination, (2) heating units and controls are somewhat complicated and expensive, and (3) unless heating units are properly installed they constitute a fire hazard.

This very brief picture of the status of grain and seed drying operations as applied to Georgia conditions has been presented as a background for the research work in this field initiated last year at the University of Georgia in cooperation with the USDA Bureau of Plant Industry, Soils and Agricultural Engineering.

In a search for new methods of drying which would overcome the disadvantages of present methods, the use of chemically dehydrated air was decided upon as having good possibilities; therefore, a study of this method of drying was begun. Calcium chloride was selected as the dehydrating agent for the initial studies since it is relatively low in cost (about 3 cents per pound) and, while not available at present in some localities, can be readily obtained from mail order houses or chemical supply concerns. Other products, such as activated alumina, might be employed for this purpose, but they are much higher in initial cost and the equipment and labor required for reactivation would not be economical.

The hygroscopicity of calcium chloride is shown in Table 1. It should be noted that, at constant temperature, one pound of calcium chloride will take up a much greater quantity of water when the air in contact with it is of high relative humidity. Fig. 1 shows the vapor pressures of calcium chloride solutions at various temperatures and solution strengths. Let us assume that air to be dehydrated has a temperature of 75F and a relative humidity of 75 per cent. Under these conditions the vapor pressure is approximately 16.3 mm of mercury. The same vapor pressure exists for a 31 per cent calcium chloride solution in which the calcium chloride is of a commercial grade with 22 per cent water of hydration; therefore, a stronger solution with lower vapor pressure is required in order to absorb moisture from the air. In this particular case, a solution weaker than about 31 per cent would have a higher vapor pressure and would lose moisture to the air.

TABLE 1. HYGROSCOPICITY OF CALCIUM CHLORIDE

(Pounds of water taken up by one pound of flake calcium chloride at different humidities)

Relative humidity, per cent	Temperature, deg F	Water taken up by 1 lb $CaCl_2$, lb
36	77	1.0
60	77	1.6
70	77	2.0
80	77	2.8
85	77	3.5
90	77	5.0
95	77	8.4

Fig. 2 shows the experimental drier constructed for use in this study. On the right is the circular seed bin with screened bottom, for supporting the seed, and plenum chamber beneath. On the left is the dehydration chamber with trays for the calcium chloride flakes and brine. The blower forces

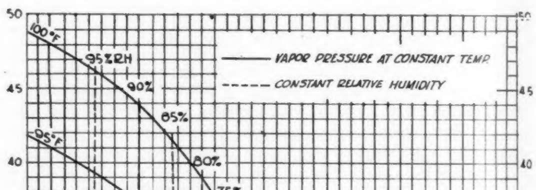

Fig. 1 Vapor pressures of calcium chloride solutions (taken from National Research Council Report No. 2F)

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Farm Structures and Rural Electric Divisions.

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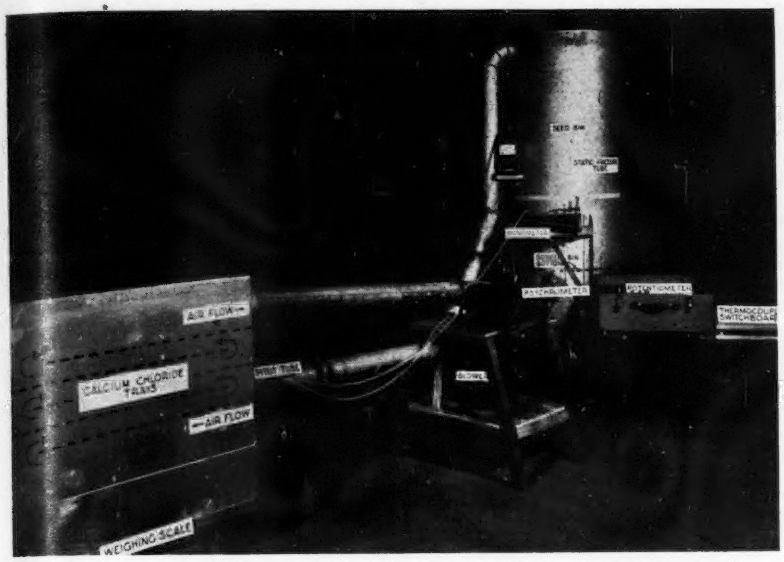


Fig. 2 An experimental drier specially built for the study of drying blue lupine seed with chemically dehydrated air

the air over the brine trays and the flake tray, and then delivers it to the plenum chamber. The partially dehydrated air passes up through the seed, picking up moisture, and then returns to the blower. Measurement of air flow rate was taken in the delivery pipe by means of a pitot tube and inclined water tube manometer. Static pressures in the plenum chamber and at different seed depths were secured with 1/4-in pipes placed across the bin diameter and having 3/32-in holes drilled 5 in on centers. Temperatures of the air and seed were obtained at various points by means of thermocouples. The relative humidity of the air in delivery and return pipes was measured with a bayonet psychrometer inserted through ports in the pipes. The seed bin and dehydration chamber were each mounted on platform scales so that weight changes could be readily measured. Moisture contents of the seed were also checked by the air oven method at the beginning and end of each test.

Returning to the discussion of properties of calcium chloride and the application of these properties for this purpose, let us again assume air entering the dehydration chamber at 75 F, 75 per cent relative humidity, and a vapor pressure of 16.3 mm of mercury. If the calcium chloride solution on the burlap tray over the collection pan is above 31 per cent in strength, some moisture will be removed from the air. Thus as the air passes to the tray above it will be of lower moisture content. Since moisture has been removed and heat of vaporization released, the air temperature will be higher. Under these conditions the vapor pressure will become lower as the air passes from tray to tray. However, the strength of the calcium chloride solution increases at each tray in going from the bottom to the top of the chamber, and, consequently, the vapor pressure of the solution decreases thus permitting absorption of moisture from the air. The vapor pressure of crystalline calcium chloride is, of course, much lower than that of the air so that the air loses considerable moisture as it passes over the flake tray.

Table 2 gives a comparison for Test 3 of the vapor pressures of the water in the air entering the dehydration chamber and the vapor pressure of the brine collected at the bottom of the chamber. It will be noted in several instances that the brine has taken up almost as much moisture as is possible thus tending to bring the vapor pressures of the brine and air moisture into equilibrium. During the first 8 hr no brine was collected since it required that much time to work downward to the drain. As a consequence, at the end of 12 hr of operation the specific gravity of the brine was higher than that collected thereafter since it was not exposed to the entire area of trays during all of the 12 hr of operation. Toward the end of the test the specific gravity was again higher due to the slower drying rate at the lower moisture content of the seed. The specific gravity of the brine was much higher for run 9 than for run 8. This was due partially to the fact that, when the blower was shut off at the end of the test, a considerable quantity of high strength brine, which had been held on the trays by air pressure, drained into the collection can before the specific gravity was measured. Apparently the relative humidity reading for run 8 is in error, and, consequently, the calculated vapor pressure is lower than would be expected, since there is no logical reason for a lower relative humidity at this period.

Some of the other results of the tests are given in Table 3. In these tests we found that the efficiency in the use of calcium chloride was increased as much as 185 per cent by passing the air, as just described, over the brine first, (Test 2) as compared with passing it over the flakes first and thence downward over the brine (Test 1.) The direction of air flow was the same for Tests 2, 3, and 4. In the several tests run during the past season the reductions in the moisture content of the seed varied from 15.8 to 20.4 per cent on a dry basis. An air flow rate of about 34 cfm per sq ft of bin floor area proved to be almost 12 per cent more efficient

TABLE 2. VAPOR PRESSURES AND RELATED DATA FOR TEST 3

	Air entering dehydration chamber			$CaCl_2$ brine collected	
Run	Dry bulb temperature, deg F	Relative humidity, per cent	Vapor pressure, mn-Hg	Specific gravity	Vapor pressure, mn-Hg
1	76	70	16.1		
2	80	69	18.1		
3	79	72	18.3		
4	79	72	18.3	1.352	13.5
5	80	69	18.1	1.302	16.3
6	82	66	18.5	1.302	17.6
7	81	66	17.9	1.302	17.3
8	82	53	14.8	1.318	16.5
9	81	56	15.2	1.348	14.9

in the use of calcium chloride than a rate of about 18 cfm. Possibly the additional benefit was derived from increased turbulence in the dehydration chamber *(Continued on page 118)*

TABLE 3. GENERAL RESULTS OF TESTS

Direction of air flow	Test 1 (over flakes first)	Test 2 (over brine first)	Test 3 (over brine first)	Test 4 (over brine first)
Average rate of air flow, cfm per sq ft of bin floor	18.6	17.8	33.9	30.8
Depth of seed, in	12	12	12	24
Original weight of seed, lb	170.0	171.0	172.5	350.0
Calcium chloride used, lb	44.5	12.2	10.6	27.5
Initial moisture content (dry basis), per cent	31.2	34.2	31.9	32.1
Final moisture content (dry basis), per cent	11.1	13.8	16.0	16.3
Moisture content reduction (dry basis), per cent	20.1	20.4	15.9	15.8
Calcium chloride used per 100 lb of seed (dry basis) per 1 per cent reduction (dry basis), lb	1.71	0.60	0.51	0.66
Cost of calcium chloride at 3c per lb for reducing moisture content of 100 lb of seed 1 per cent (dry basis), cents	4.9	1.9	1.5	2.0

Effects of Conservation Practices on Runoff

AGRICULTURAL engineers, either as citizens qualified to judge such matters or as administrators and technicians in the public service, are deeply concerned with runoff from agricultural lands. To discharge properly their professional and civic responsibilities they must have access to information on magnitude and frequencies of rates and amounts of runoff and of floods on upstream tributaries. In estimating benefits from flood abatement by conservation practices they must know quantitatively the effect of such practices on erosion, runoff, stream flow, and sedimentation. One of the major objectives of the Committee on Agricultural Hydrology of the American Society of Agricultural Engineers is to assist A.S.A.E. members and others in obtaining such information and to encourage original research in this phase of agricultural engineering.

A subcommittee of the above-named committee — the Subcommittee on Runoff — has been trying to make available the results of research in this field and to point out the deficiencies in basic information which must be made up by further research. Papers on rates of runoff were presented at the 1946 and 1947 A.S.A.E. annual meetings, and at the 1947 winter meeting in Chicago the effects of conservation practices on runoff were discussed. The participants in this discussion were members and guests of the Society who have been engaged in soil and water conservation research for over a decade and who have done their work in widely separated localities and under markedly different types of climate, soil, and cropping practices. Following is a summary of the conclusions of five of these research workers, based on their observations:

The observations of D. D. Smith, research project supervisor, Soil Conservation Service, USDA, stationed at Columbia, Mo., based on some 12 years of research work on runoff and erosion in two important areas — the Claypan and the Shelby soils in Missouri (McCredie and Bethany) — are as follows:

"The recent activity in connection with upstream flood control has focused attention on the inadequacy of research information in this field. Research work of the Soil Conservation Service has been largely concerned with methods of reducing soil erosion. With few exceptions, the studies have been made on small fractional acre plots. Methods for application of these results to larger field areas have been developed from a meager amount of data. These data show that soil losses from field areas are appreciably higher than from the small fractional acre plots. This was confirmed by soil loss measurements from watersheds of a few acres in size. The losses have been expressed as annual rates of erosion to measure the adequacy of cropping, soil management, and conservation practices for maintenance of soil productivity. Runoff has been expressed likewise and inadvertently used in some instances as a measure of flood reduction. Actually when flood-producing rainfall has occurred, runoff from small plots on claypan soil has been nearly as high under soil-conserving rotations as under cropping systems allowing high soil loss, although when annual runoff was considered, the reduction was one-third.

"Runoff from pastures that included the full slope length has exceeded that from small plots 90 ft long under similar cover condition by 4 in per year during 2 years of measurement on these Claypan soils. While this is considered the result of a return of subsurface flow to surface flow on the longer slopes, further measurement and research will be required to determine the relationship and its effect on flood flows.

"A wide difference of opinion exists as to the effect of terracing on the amount and rate of runoff. Terraces are considered by some to improve drainage on claypan soil by interception of subsurface flow. There is no research information on this subject.

"On the Shelby soil, terracing reduced the annual amount of runoff by 30 per cent. For the nine most severe storms occurring during 8 years of measurement the average reduction was only 11 per cent. For two of the storms there was slightly more runoff from the terraced watershed than from the one operated with field boundaries. With contour farming, the average reduction in annual runoff was 20 per cent, with an average reduction of 2 per cent for the nine most severe storms. For four of these storms there was more runoff from the contoured watershed than from the check. The maximum rate of runoff from the terraced watershed was less than for either the check or contoured watershed for all storms, whereas the contoured watershed had a higher rate than the check for two of the nine. Data of this type are not available for any of the other soils in Missouri.

"Waterway design for the common grasses has been investigated. This would provide sufficient design information for terrace outlets, if applicable runoff data were available. It is available only for the Shelby soil of Missouri. Stabilization of drainageways on large areas by vegetation and structures as contemplated will require a large proportion of upstream flood control funds. There has been little if any research applicable to this problem except for rating tests on spillway capacities and tail water energy dissipation."

N. E. Minshall, research project supervisor, Soil Conservation Service, USDA, stationed at Madison, Wis., has charge of two of the few projects where studies are made of runoff from agricultural areas ranging in size up to 300 acres; these studies on four watersheds at Edwardsville, Ill., and four at Fennimore, Wis., have been under his direction since their inception in 1938. Mr. Minshall's observations on runoff from small watersheds typical of the claypan prairies and the loess areas of the Upper Mississippi region are as follows:

"The purpose of the runoff studies at Edwardsville and Fennimore is to determine rates and amounts of runoff for use in the design of conservation practices in the claypan prairies and in the loess areas of the Upper Mississippi region. Although they were not intended to determine the effects of conservation practices, many of the records are of considerable interest and value for this purpose.

"Records for nearly 10 years on two of the watersheds (27 and 50 acres), and for 5 years on a 12.6-acre terraced area at Edwardsville, show the following for the claypan prairies.

"There appears to be a good relationship between total rainfall and total runoff for relatively long periods of time such as a calendar year or any other 12-month period. For such periods the rainfall runoff relationships show the greatest runoff from cultivated land, less from pasture, still less from a terraced-cultivated area, and least from alfalfa. However, for critical storms which must be considered in design and in flood control, the picture is different. During three of ten critical storms the cover on the 27-acre watershed was 100 per cent hay and pasture (96 per cent alfalfa). During one storm it was 84 per cent hay and pasture. During four storms it was 52-56 per cent in hay and pasture and the remainder in small grains and corn. During the remaining two storms pasture was 4 per cent and grain and corn were 17 and 69 and 79 and 27 per cent, respectively. Natural storms are seldom if ever identical; it is nevertheless interesting that both the lowest and the highest infiltration rates occurred when the watershed was 100 per cent in hay and pasture. There is definitely no clear-cut indication as to the degree to which this excellent cover of alfalfa affected rates and amounts of runoff on this watershed.

"Because of difference in size of watersheds and differences in amounts and intensities of rainfall, rates and amounts of runoff cannot be properly compared. Retention on the 50-acre pasture watershed was greater than on the 27-acre for six of the ten storms and less for the remaining four, of which two occurred in 1942 and 1943 when the 27-acre watershed

A contribution of the Committee on Agricultural Hydrology, American Society of Agricultural Engineers — D. B. Krimgold (chairman), I. D. Mayer, R. W. Trullinger, C. S. Slater, W. D. Potter, T. W. Edminster, F. G. Bell, and L. L. Kelly.

was in alfalfa. Only four of the ten storms occurred before 1943 when the terraced area was discontinued. For three of these storms the retention on this area was less than on the unterraced 27-acre watershed.

"No significant relation between rainfall and runoff, not even for a 12-month period, was found on the Fennimore watersheds. The soils in this loess area are deep and permeable and rates as well as amounts of surface runoff are much lower than at Edwardsville. With the many uncontrolled variables involved, it is difficult to draw definite conclusions. The records do, however, show more or less consistently that on these deep, permeable soils, total runoff for critical storms is considerably greater from the larger watersheds. Thus the runoff from a 5-in rain on July 25-26, 1940, was 0.43, 0.53, 0.96, and 0.81 in from the 22.8, 52.5, 171, and 330-acre watersheds. With the limited facilities available for this work it has not been possible to investigate the reasons for occasional reversals in this trend or to explain why the runoff from the 330-acre watershed appears to be somewhat less than from the smaller 171-acre watershed.

"The floods of June, 1947, in the area represented by the Fennimore, Wis., watersheds are of interest in connection with the records from the experimental watersheds. A 4.25-in rain on June 12-13 resulted in total runoff of 0.75 in on the 330 and 171-acre watersheds, and 0.36 and 0.19 in on the 52.5 and 22.8-acre watersheds, respectively. Rates of runoff from the watersheds were but one-third of the maximum rates recorded in the 10 years of record. Yet this rain on a nearby 15-sq-mi drainage area caused the worst flood in 50 years in the city of Boscobel, Wis. Sixteen days later, on June 28, a storm of 2.75 in produced 0.38 in runoff on the 330-acre watershed, 0.27 in on the 171-acre, and 0.32 in and 0.20 in on the 52.5 and 22.8-acre watersheds. Rates of runoff were somewhat higher than on June 12-13. The flood produced by this rain at Castle Rock (drainage area, 40 sq mi), 8 miles northeast of Fennimore, was the worst in 39 years. The damage to roads and bridges in Grant County alone was estimated at over one-half million dollars.

APPLICABILITY OF DATA FROM SMALL WATERSHEDS

"It appears, therefore, that the combined effect of rainfall amounts and intensities, conditions of soil moisture and cover, and size of area is of such importance that the data from small watersheds must be modified greatly before it can be applied with reasonable accuracy to the larger drainage areas. To make such intelligent application of the present data will require a large amount of additional research."

E. H. Kidder, hydraulic engineer, who has been connected for several years with the U. S. Soil Conservation Service research projects at Urbana and Dixon Springs, Ill., presents the situation in two additional important areas in the Middle West, as follows:

"Contour farming as practiced in Illinois is not always highly effective in controlling flood runoff from corn and small grains. A thunderstorm on June 2, 1942, produced 2.04 in of rainfall in 61 min. The 15 and 30-min rainfall intensities would classify the storm as a once-in-two-year frequency, while the one-hour precipitation would classify it as an eight-year frequency (Yarnell). Runoff from the contoured corn and oats plots exceeded the runoff from the plots up and down the (2 per cent) slope. Another flood-producing storm occurred on June 19, 1946, when 2.24 in of rain fell in 144 min. The 15 and 30-min rainfall intensities classify the storm as a once-in-four-year frequency (Yarnell). Antecedent rainfall on the preceding day amounted to 1.57 in. The runoff from plots of contoured corn was 63 per cent, as compared to 61 per cent from non-contoured plots.

"High flood runoff is not necessarily a function of high-intensity rainfall. At Dixon Springs during the night of September 24-25, 1945, between 6.63 and 7.10 in of rain fell on the plots in a 9-hr period. The rainfall intensity did not exceed the two-year frequency for 5, 15, and 30-min intensities, but the total rainfall did exceed the 8 and 16-hr total expectancies for Yarnell's 100-year frequency. From contour-planted, smooth-surfaced corn plots, varying in length from 35 to 210 ft and on slopes of 5 and 9 per cent, the percentage runoff ranged from 51.1 to 60.2 per cent. The rate of runoff from these same plots ranged between 2.8 and 4.3 in per hr per acre. Pasture plots under close and regulated grazing intensities showed little variation in the percentage of runoff, which ranged from 49.3 to 56.4 per cent. Antecedent rainfall during the month was 2.88 in, most of which fell during the first 13 days.

"Since the runoff from the cultivated and the pasture plots are so nearly the same, it appears that under conditions of a large storm even grass crops in southern Illinois are not effective in greatly reducing flood runoff."

The following observations based on his experience with 43 plots and one 19.2-acre watershed were contributed by John R. Carreker, agricultural engineer of the Southern Piedmont (SCS) Conservation Experiment Station at Watkinsville, Ga. Mr. Carreker has been measuring and studying runoff and erosion in the Southeast for 10 years:

"The cropping practices used on Watkinsville plots vary from continuous row cropping with cotton to continuous ground cover with sericea lespedeza.

"Results to date show that the amount of soil lost is markedly affected by the cropping practice. With the prevailing practice of continuous row cropping, the erosion losses are high. Complete ground cover, even on the 11 per cent slope, reduces the erosion to an almost negligible amount.

"This recently acquired knowledge on erosion control now provides a basis for evaluating cropping practices for conservation purposes, as well as for crop yield responses.

GROUND COVER LESSENS AMOUNTS OF RUNOFF

"Ground cover lessens the amounts of runoff, but generally not to the extent that it reduces the erosion loss. Runoff rates on the plots with ground cover usually are lower than on the unprotected plots. But for critical storms there may be little difference in runoff rates and amounts from the land in row crops and from that in close-growing crops.

"For instance, the rain of nearly 5½ in on January 6, 1946, caused the nearby Oconee River to reach its highest flood stage in recent years. This rain was very widespread and was characterized by a period of low rate of rainfall for several hours followed by high rates for a short while. After 3½ in of rain had fallen at rates of less than 1 in per hr during a period of several hours, 1½ in then fell in less than 1 hr. Maximum rates were 6.0 in per hr for 5 min and 4.4 in per hour for 15 min during this latter portion of the rain. *Runoff rates* from all ground cover conditions measured on the small plots were practically equal to the *rainfall rates.*

"Soil moisture conditions during this storm were very conducive to high runoff, as the soil was thoroughly saturated before the heavy rain came. The subsoil percolation rate apparently controlled the surface infiltration rate.

"The maximum rainfall rates measured during the rain were not as great as we normally have each year, yet other conditions combined with these rates to cause a flood of considerable magnitude. How frequently will these conditions recur? We don't know.

"For this same rain, the maximum rate of runoff on the 19.2-acre watershed was only 2.3 in per hr. There was about the same degree of ground cover here as on the small plots with good ground cover where the maximum runoff rate was above 4 in per hr. Slope and soil types were similar.

"Why these differences in magnitude of runoff rates between areas of different sizes? There are several suppositions why, such as differences in time of concentration, increased opportunity for surface storage, variation in soil, etc. All these conditions were apparently equalized in the areas under discussion. Therefore, we must admit there are a number of things we don't know concerning areal expansion of plot data on rainfall and runoff."

What are the results of a decade of research in the Blacklands of Texas? This question is at least partially answered in the following statement by R. W. Baird, research project supervisor of the Blacklands (SCS) Experimental Watershed, Waco, Tex.:

"At the Blacklands Experiment Watershed, facilities are available to study the effects of land-use practices on rates and

amounts of runoff and to a smaller degree on soil losses. The experimental layout has two quite similar areas of about 300 acres each with each further divided into smaller areas. Runoff measurements are available from each of these areas and soil loss measurements from some of them.

"From the record through 1945, commonly used conservation practices have resulted in lower peak rates of runoff, but the effect appears to be slightly less for the larger floods. On the heavy black clays of the area during long storms or rainy periods a condition is reached where *almost all rainfall* appears as *runoff*. Under these conditions only those practices which reduce the velocity of flow or amount of temporary storage will affect runoff rates. The temporary storage of water in terrace channels plays an important part in the reduction of peak flows.

"The effect of conservation practices on the total amount of runoff is not as clearly defined and more data are needed before definite statements on the effect can be made. When the soil is relatively dry at the start of the storm period, there seems to be slightly less runoff from the areas with conservation practices. During long periods of wet weather when all soil moisture deficiencies are satisfied there seems to be little or no difference between the treated and untreated areas."

SUMMARY

The observations quoted above were made by qualified, responsible research workers who have studied these problems firsthand and for extended periods of time. The data presented are not sufficiently consistent or direct to justify definite conclusions. However, there is a sufficient trend in the data to cause grave concern to engineers and other professional men who are called upon to make decisions and recommendations, or to plan and to execute flood abatement by conservation practices and by other headwater measures.

There are a number of fundamental questions to which definite answers must be found before the validity of present methods and procedures can be ascertained.

Movement of water into and through soils is a subject on which too little is known. We do not know definitely all the factors involved, let alone the natural laws which govern this quantitative relationship. Yet rates of infiltration and subsurface runoff—the keystones of present methods in estimating runoff and of determining effects of land use and of conservation practices—cannot be properly determined without knowledge of the natural laws governing movement of water into and through soils. Neither can we hope to solve satisfactorily the many problems in drainage without this knowledge.

There are other subjects on which we do not have sufficient knowledge to interpret properly the results of experiments. Evapotranspiration must be better understood before we can tell how much water can be stored in various soils with good protective cover. The natural laws governing evapotranspiration have yet to be formulated. Neither is there enough information for solving even empirically the many problems involving evapotranspiration.

How much do we know about relation of drop size to infiltration and of drop size to intensity in natural rainfall, or about morphology of natural storms? The records show that the time of occurrence of intense rainfall within a storm has an important effect on runoff and erosion from unprotected land, but why and how much? How often is one or another rainfall pattern likely to occur at a given locality? The "practical" man might consider it too far-fetched to try to solve immediate problems by embarking on long-range fundamental research as suggested above. He might argue that results from such research will not be available in time to do much good in connection with the problems we are facing today. Those who have tried to find solutions to these problems by "practical", short-time "field investigations" "applicable to local conditions" have found, to their dismay, that at the end of 10 years or more of hard work they had a mass of seemingly confusing, unrelated data which cannot be analyzed and properly applied without a clear understanding of the natural laws and processes involved. There are many problems of an applied nature which are still unsolved because the fundamental information necessary for their solution are lacking.

The participants in this discussion were unanimous in the conclusion that close-growing vegetation greatly reduces erosion even for critical storms. This means that the runoff from properly controlled land, which for critical storms may be quite considerable will be relatively clear. Will this clear water increase or decrease bank and streambed erosion? On this we have many conflicting opinions and notions but no research. A good deal of thought has been given lately to water-flow retardation by reservoirs on small upland tributaries. Spillway storage on such reservoirs is to be depended upon to regulate the flash flows. But the design of such systems involves runoff hydrographs from small drainage basins of which practically none are available. The present procedures and methods involve the determination of total runoff by the "infiltration theory" and the use of the unit hydrograph and distribution graph to obtain rates and stages of streamflow. Attempts to develop unit hydrographs with the unusually complete and detailed records of runoff and of rainfall at Edwardsville, Ill., show that for small drainage basins even detailed records of rainfall amounts and intensities are not sufficient.

Serious as may be the consequences of floods and erosion, their complete control cannot be accomplished in a few years or even a few decades. The gravity of these problems make it neither practicable nor desirable to wait for research findings before any work is done. Responsible members of the engineering and of other professions involved must do their best with what is available, but must also call attention to the serious deficiencies in research in this field and must demand research on a scale commensurate with the need for the information. Results of adequate research are the tools of the engineers and of other technicians. Without the tools they cannot be expected to perform their function properly.

Unit Operations

(Continued from page 99)

breakdown into botanical components; a combination of mechanical, gravity, and pneumatic separation, and movement of the separated components. From this viewpoint the combine and all of its parts are more easily understood for purposes of effective operation, adjustment, repair, or refinement of design.

These basic operations may be found in slightly modified forms in other machines. This fact suggests that our study of agricultural machinery could be greatly simplified by the unit operations approach. Different machines exist because of a need to fulfill functional requirements demanding different combinations of units and unit operations.

The unit operations viewpoint helps the engineer to get an operational view of the whole problem, to define in engineering terms the over-all job to be accomplished, the reason for the application of engineering.

Then it helps the engineer to picture within the whole problem the various parallel and consecutive relationships of its parts. Each part generally turns out to be a man-sized work unit, and a field of application for certain groups of engineering principles.

Under the microscope of engineering analysis the individual problems in these work units can be identified, segregated, and classified according to the specific fields of engineering or other technology involved.

Physical conditions and the ranges of various physical values involved begin to show up in detail. Known and unknown elements of each problem become evident. Basic similarities are emphasized and differences due to special application are minimized.

The unit operations idea focuses attention on basic engineering principles, rather than on superficial differences in their application. It emphasizes the similarity of the engineering involved in a wide variety of applications. Air flow is air flow in a combine, carburetor, cow stable, or the great outdoors. Any peculiarities associated with a given problem should be developed from basic known facts.

In this narrow-down range of engineering subject matter the engineer will know, or if on *(Continued on page 124)*

How to Increase the Life of Asphalt Roofing

By James L. Strahan
FELLOW A.S.A.E.

RIGHT now the asphalt roofing industry is engaged in a program of standardization of application recommendations. Application of asphalt roofing products has been largely a matter of the individual preferences of dealers, applicators, and users, and based upon their experiences in widely distributed areas of the country and under varying local circumstances. It is true that manufacturers have prepared and distributed application specifications (direction sheets) with their products; and it is surprising how consistent these have been, considering that thirty or more of them developed their methods and recommendations independently over the years. Unfortunately the instruction sheets are too often disregarded by those who handle and apply the products.

Realizing that the best products, improperly selected and applied, cannot be expected to give good service, and therefore can be expected to result in loss of public confidence and acceptance, the industry, through the agency of its trade association, The Asphalt Roofing Industry Bureau, decided about three years ago to take steps to influence the manner in which its products are used after they pass through various channels of distribution to the using consumer. It set up an engineering committee composed of men drawn from member companies who have supplemented their engineering training with wide field experience and who are in a good position to know what good application practices are, from years of observation and servicing. To this committee was assigned the primary task of preparing standard application specifications which would include, not only the details of applying the many different types of products, but also the important characteristics of good roof decks, both old and new, together with good methods of flashing. This assignment is approaching completion, and in the near future each company in the industry will be having an opportunity to revise its instruction sheets to make them consistent with the committee recommendations. Having been closely associated with this project almost from its inception, my guess is that such revisions will not be drastic, for the reason that technical differences for the most part are minor and relatively unimportant. The values that will accrue to both manufacturers and users of the products must be evident. The customers will know what the industry recommends and will have confidence in it because it will represent the best engineering thinking available, completely divorced from personal predictions. And knowing this, they will be in a position to demand good application. This cannot fail to result in a general upgrading of application practices and consequent improvement of performance.

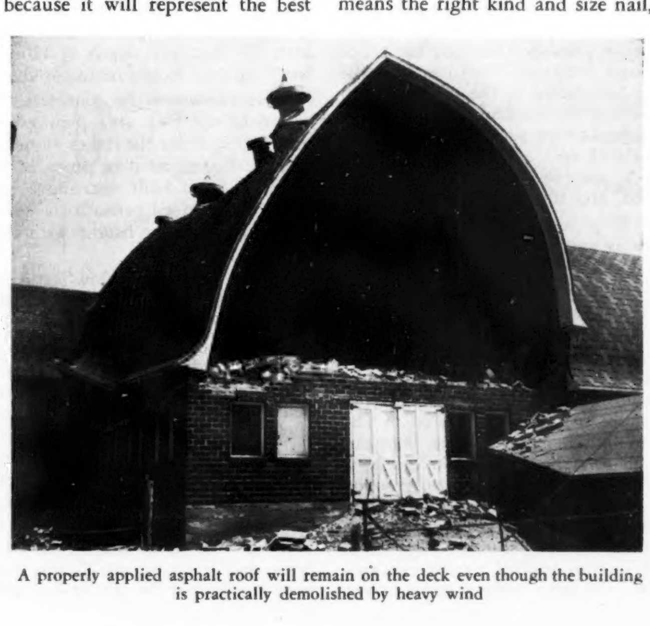
It is possible now to present a preview of these specifications, particularly as they relate to application of the more popular items in the open plains area of the Middle West. Attention has recently been focused on certain types of failures which seem to be more prevalent in windy areas. Insurance companies have noticed an increasing number of wind damage claims, and naturally want to reduce or eliminate the trouble. In this their interests are exactly parallel to those of the roofing industry which is now concentrating its engineering resources to meet this situation.

Both standard application specifications, and those which might be termed "wind-resistant" specifications are concerned with roof decks, methods of flashing, and application of the products. In addition to application specifications, recommendations with respect to the selection of products for different purposes vary as between standard and wind-resistant conditions. Some products, such as roll roofings, when applied in the usual manner by the exposed nail method, and even 36-in wide sheets applied by the concealed nail method, will probably no longer be recommended for use in exposed locations. Double coverage rolls and 18-in sheets applied by the concealed nail method are the only roll roofing products that will be so recommended, whenever the full life expectancy of the material is demanded.

Under ordinary standard conditions the popular 3-tab square-butt strip shingle is applied 5 in to the weather and secured with 6 nails. When a heavier roof is demanded, this same shingle can be exposed 4 in to the weather to increase its weight by 25 per cent, making what amounts to a triple coverage roof of it. Applied in this manner the tabs offer greater resistance to wind action. Practically certain 100 per cent protection against wind damage can be obtained even in the most exposed locations, when the 5-in exposure is used, by cementing down the tabs with quick-setting asphalt cement. This is accomplished by using a caulking gun to place a spot of cement about as large as a 50-cent piece under the center of each tab and on the surface of the underlying shingle, thereafter pressing the tab down firmly against the cement. This same treatment can be applied to two and three-tab hexagon strip shingles to render them windproof.

Of course the really important resistance to blowoff is provided by the nails. Correct nailing is vital. Correct nailing means the right kind and size nail, the right number of nails, and the right kind of deck into which to drive the nails.

All nails should be large-headed, hot-galvanized, barb-shanked nails. The heads should be at least ⅜ in in diameter; 7/16 in is better. The shank is 12 gage for the nail having a ⅜-in head, and 11 gage for the larger one. The length of the nail varies with the circumstances. When roll roofing is being applied to a new wood deck, the nail should be 1 in long. When a heavy asphalt shingle is being applied over an old wood shingle roof, the nail must be long enough to penetrate two or three plies of asphalt fabric, two or three plies of old wood shingles, and at least ¾ in



A properly applied asphalt roof will remain on the deck even though the building is practically demolished by heavy wind

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December, 1947, as a contribution of the Farm Structures Division.

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into the underlying wood deck. This will call for a nail not shorter than 1¾ in and perhaps 2 in. Between these two extremes the nail length must be adjusted to the conditions, the main consideration being that the shank should penetrate to the under surface of the wood deck sheathing; and it doesn't matter much if it projects all the way through.

Finally, the number of nails prescribed by the manufacturer for the product being applied should be driven at the points indicated on the direction sheets. Six nails are recommended for 3-tab square-butt strips, 4 nails for 2 and 3-tab hex strips, and 2 nails each for all individual shingles. In addition to the nails, many individual shingles require a special fastener or staple to be applied at an exposed corner. All such fasteners are designed to penetrate the two upper plies of roofing without going through the ply that lies on the deck. They do not, therefore, produce an exposed passageway through which water can penetrate to the deck from the surface of the roof.

To get the best service from any roofing material, the deck must be right, and this is true of asphalt roofing products. It does not take much distortion of the surface of the deck to disturb the lay of the roofing material whether it be a roll product or shingles. When this happens, wrinkles occur or the shingle tabs cock up.

The deck must present a smooth flat surface that will remain smooth and flat throughout the life of the structure. It must, therefore, be supported adequately by the substructure, and it must be dry when the roofing is applied and remain dry thereafter. This requires the use of properly seasoned framing lumber of proper section and spacing; it calls for narrow rather than wide deck sheathing, and tightly matched sheathing boards. If the deck is to be dry when the shingles are applied, the sheathing must be well seasoned at the time it is nailed down, and it must be protected with No. 15 roofers felt from that time on. It is good practice to lay only as much deck sheathing as can be covered the same day with roofers felt. The underlayment covering must be a vapor permeable material rather than a vapor barrier to minimize the possibility of frost accumulating between it and the deck sheathing under unusual moisture conditions. Asphalt saturated felt is vapor permeable. Coated felt such as light-weight smooth roll roofing is a vapor barrier and should never be used as an underlayment. If these precautions are followed, it is very probable that the deck will be dry when the shingles are applied.

PROVIDE VENT FOR VAPOR PRESSURE EQUALIZATION

In order to insure that this condition will continue after the building is in use, it is desirable to provide for a vent to permit of equalization of vapor pressures between the space immediately under the roof and outdoors. This can take the form of a louvered opening constructed in the wall high up under the eaves in the gable end of the building. Moisture will then not be able to accumulate in sufficient quantity to dampen the under side of the roof deck and cause warping of the boards. To repeat, it is important to have the deck dry when the shingles are applied, and to keep it dry thereafter during the life of the structure.

The pitch of a roof deck is another characteristic which will determine the type of roofing that can safely be used with expectation of normal service. In general, it can be stated that, everything else being equal, the steeper the pitch, the better the performance that can be expected. The industry recommends that no shingle be used on a deck having a rise of less than 4 in per horizontal foot of run. Only roll products should be used on flatter pitches, and only certain types of roll products on slopes as low as 1 or 1½ in per foot. The 19-in selvage roll may be used on slopes of 1 in per foot but no less. Any roof flatter than this should be protected by a properly specified built-up roof. When ordinary roll roofing is to be used on slopes as low as 1½ in per foot, it should be applied by the concealed-nail method and should have at least a 4-in headlap. In windy areas such roofing should be applied in 18-in strips, not 36-in. Roll roofing applied by the exposed-nail method should be limited to decks with a slope of not less than 3 in per foot, and should never be so applied in windy locations except as a temporary covering.

Asphalt roofing properly selected and applied is a permanent structural material. It is not paper; it is not a makeshift; it is economical but not cheap. It has matured during the last 50 years of development into a material which, since 1933, has accounted for 75 per cent of all roof coverings shipped annually in the United States; during and since the World War II for 85 per cent. But, like any other structural material it serves best only when properly applied. The industry, having long since emerged from immaturity, knows what proper application is.

It is unfortunate that lack of attention to recognized technical standards of applying the various products has resulted in failure in some instances to provide satisfactory service. The industry is now making a determined effort by using every resource at its command, to promote an ever broader understanding of those techniques that have stood the test of time. It wishes to cooperate with insurance companies, educational institutions, and the trade in general to that end. Fully realizing that its own interests and those of its customers, both distributors and users, are parallel and complementary, it intends to go forward vigorously with this program designed to improve selection and application practices.

Drying Seed Grain with Calcium Chloride

(Continued from page 113)

which would result in a better scrubbing action over the surface of the trays. On the basis of Test 3, with calcium chloride at 3c per lb, the chemical cost for reducing the moisture content of the blue lupine seed from 24 to 14 per cent on a wet basis would be about 17c per 100 lb of combined seed. The time required for this reduction (15.3 per cent dry basis) was slightly over 24 hr. Since a much greater proportion of seed is probably harvested at 18 per cent (or less) and is often reduced to 12 per cent (wet basis), this reduction (8.4 per cent dry basis) should be accomplished at a chemical cost of about 10½c per 100 lb of combined seed.

Certainly the chemical cost is not excessive and, while the experimental method required 50 to 120 per cent more time than is usually necessary in commercial driers using supplemental heat, the time factor is not of such prime importance in a farm drier. The capacity of such a drier ordinarily would need to be sufficient to take care of the daily harvest from one combine. This would mean a probable capacity of 5 tons where a 5-ft combine is operated about 7 hr a day with an average production of slightly less than 1000 lb of seed per acre. With a seed depth of 12 in, approximately 200 sq ft of bin floor area would be required.

One feature to be considered in a drier of this capacity would be the tray area required which would be somewhat over 200 sq ft for the flakes alone. In addition, five trays, each of similar area, must be provided for the brine drip. However, with the trays built one above another, the entire assembly could be arranged beneath the seed bin or bins, thus utilizing more of the room height without requiring additional floor space.

Our studies of air flow-static pressure-seed depth relationships for blue lupine seed have shown that, if an abnormal amount of foreign matter were not present, the static pressure should not exceed 0.3 in through a 12-in seed depth with an air flow of about 35 cu ft per sq ft of bin floor or drier cross section exposed. Allowing 0.2-in resistance in the drier, a fan delivering roughly 6500 cfm against a total static pressure of about ½ in would be needed. This requirement would be met by a 21-in propeller fan, driven by a 1½-hp motor, or a 21-in, forward-curved-blade centrifugal fan.

We are planning to build a drier, of capacity about as described, in time to be ready for lupine harvest next spring (1948). The drier will be tested under actual farm conditions, and if found satisfactory for drying lupine seed, some tests will be run on the drying of other seeds or grain.

The Flow of Water Through Soil

By C. S. Slater

GRAVITATION, the most universal of forces, is in most cases the major force in the transmission of water through wet soils. However, a tendency is evident in elementary discussions of soil water movement to ignore gravitational force and stress the effects of capillary forces. This tendency may be merely an illustration that familiarity breeds contempt; nevertheless a unified explanation is needed of the phenomena of soil water movement that result from the combined forces of gravitation and capillarity. In this paper an effort is made to develop such an explanation by showing in brief the general applications of well-known physical laws. More detailed discussions of these laws are to be found in physics textbooks. It is hoped that readers will make their own more specific applications and thus develop a logical, unified basis for interpreting observed phenomena of the movement of water in soils.

General Conditions of Gravitational Flow. When a column of uniform soil is so wet that flow of water through it results from gravitation alone, this flow is analogous in most respects to the flow of water by gravity through a vertical pipe of uniform diameter. In both cases flow takes place under tension or negative pressure, that is, under pressure less than that of the atmosphere. Maximum tension is observable at or slightly below the pipe inlet or the corresponding soil surface. Water is delivered from the outlet or the base of the soil column at atmospheric pressure. These similarities will be made clearer by reference to Fig. 1.

Velocity and Tension in a Frictionless System. Fig. 1 is a diagram of a vertical pipe through which water flows continuously from a constant supply to waste freely at the pipe outlet. Aside from the influences of friction and the tensile strength of the water column, water tends to fall freely with the normal acceleration of gravity to attain a velocity of $v=gt$, where g is the acceleration of gravity and t is the time of fall. If the length of the pipe, h, is considered to be the distance through which water falls from a point of zero velocity and zero pressure (this is a mild distortion of fact if the water over the pipe is kept shallow and atmospheric pressure is considered a zero point of reference), then the velocity of freely falling water at the pipe outlet is equal to $v=\sqrt{2gh}$, and its kinetic energy $ke=\frac{1}{2}mv^2$, where m is the mass of water under consideration. It seems unnecessary to do more than state these formulas here. Their derivation is available in almost any book on general physics.

This paper was presented at the annual meeting of the American Society of Agricultural Engineers at Philadelphia, Pa., June, 1947, as a contribution of the Subcommittee on Soil-Plant-Water Relations, Committee on Agricultural Hydrology, Soil and Water Division.

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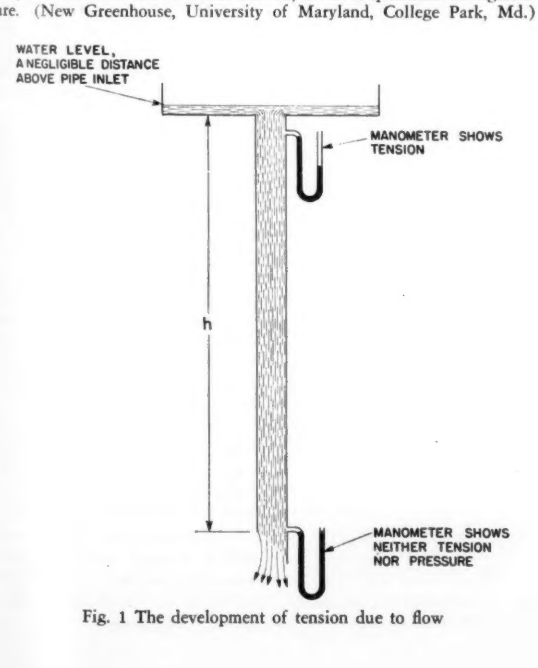

Fig. 1 The development of tension due to flow

An objection can be raised that the water in the pipe of Fig. 1 is not falling freely. Any object falling freely falls with an accelerating velocity, whereas, under the conditions of Fig. 1, as soon as the water enters the pipe it must attain a velocity that is identical with the outlet velocity. Otherwise the pipe could not be kept full. In effect, water that has entered the pipe must "pull" after it more water, and impart to it a velocity that is greater than would ordinarily be given by gravity alone. This creates suction, or tension, at the pipe inlet.

The law of conservation of energy, however, demands that the velocity at the pipe outlet (friction neglected) be that of a freely falling body. The kinetic energy of velocity must equal the original potential energy of position. This is so because atmospheric pressure is the same at the outlet as at the inlet. For present purposes this pressure can be considered to be zero.

The relations of the three forms of energy — pressure, potential, and kinetic — as they are involved in Fig. 1, can be expressed by Bernouilli's theorem, stated as the equation

$$mgh+P+\frac{1}{2}mv^2=mgh+P+\frac{1}{2}mv^2$$

The m in this equation represents not ordinary units of mass but rather the mass of a unit of volume, to which pressure also applies. Such a mass is numerically equal to density, d.

Let the left-hand members of the above equation represent conditions at the pipe's inlet, and the right-hand members conditions at its outlet, and assume such values of volume and pipe length that the potential energy is equal to x. Then the corresponding kinetic energy also is equal to x, and it is known that pressure at the outlet is zero. Substituting these values,

$$x+P+x=0+0+x$$

It is seen that pressure at the inlet is negative and equal to the potential energy x, or mgh. Substituting d for m in this equation we can write

$$-P=dgh$$

which, except for the sign of P, is the equation for pressure at a depth h. In other words, the negative pressure or tension

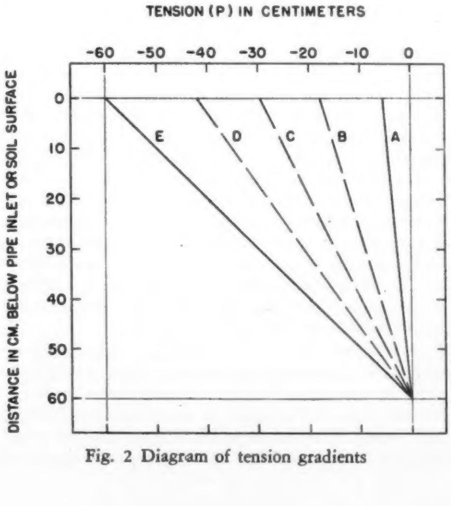

Fig. 2 Diagram of tension gradients

induced by flow at the pipe inlet of Fig. 1 is numerically equal to the positive pressure that ordinarily would be recorded at a depth h in a hydrostatic system.

Velocity and Tension in a Friction System. The pressure $-dgh$ represents the maximum tension that can be developed at the pipe inlet under an assumed condition of no energy loss, as in a frictionless system. In a system having considerable friction, for example, a tube filled uniformly with soil, the maximum tension for a given length h will be markedly less than the dgh value. Associated with this difference is a corresponding reduction in outlet velocity in the friction system. Also, a point occurs where an increase in h does not give any further increase in tension or outlet velocity.

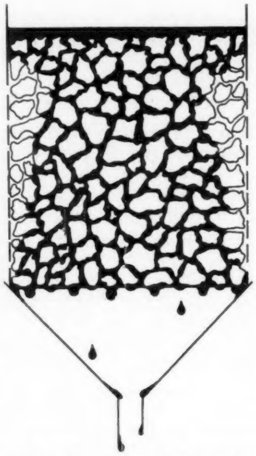

Fig. 3 Retraction of air-water interfaces

Outlet velocity has been identified as $x = \sqrt{2gh}$ for a frictionless system. Velocity can increase indefinitely as values of h increase. However, in a system having fluid friction, the energy lost to friction in each section of the pipe becomes increasingly greater as the velocity increases. A point is reached ultimately where the energy of fall that is contributed by adding another length of pipe or soil column is exactly equal to the energy that is dissipated by the additional friction in that length of pipe or soil column. At this point a terminal velocity is attained that is closely analogous to the terminal velocities reached by objects falling through the atmosphere. Since velocity is uniform throughout the pipe (or column of soil), the energy of the terminal velocity is also the energy of the maximum negative pressure or tension that can be developed at the pipe inlet.

An idealized representation of these relations appears as Fig. 2. A pipe or soil column 60 cm long is assumed. Where no energy is lost through friction, the tension in centimeters of water at the top of the pipe, due to flow, is equal to the length of the pipe in centimeters, and decreases uniformly to zero at the outlet, as shown by line E. In the uniform soil column a similar situation holds, except that the tension gradient is much reduced, as shown in line A, because of the lowering of outlet velocity that results from friction.

Outlet velocity for an idealized soil pores system can be calculated from the quantity of water transmitted, q, by the equation $v = q/tA$, where t is the time of flow and A is the area of voids in the soil cross section.

Darcy's Law and Terminal Velocity. Darcy's law as applied to soils may be expressed by the equation $v = kh/L$, where v is the velocity of flow through the cross-sectional area of the soil column, h is the pressure head, L is the length of the soil column, and k is a proportionality constant related to the character of the soil. During gravitational flow downward in soils, h is considered equal to L and, according to Darcy's law, v remains constant for any length of soil column. *This concept is not in agreement with the concept of terminal velocity that has been given.* The point to be noted is that Darcy's law is empirical in origin and has practical rather than absolute accuracy. It is most applicable where the total length of the soil column is greatly in excess of the critical h, or equivalent L, at which the terminal velocity is reached. Fortunately the critical lengths for soil columns are negligible, owing to the high frictions of soil systems.

Character of Flow in Open and Sealed Soil Columns. Tension develops as a result of flow in a pipe completely filled with water as shown in Fig. 1. Consequently there is a tendency for the pipe to collapse, to decrease in diameter, or to "suck air" owing to differences in internal and external pressure. Collapse and the advent of air are prevented by rigidity and impermeability of the walls of the tube. In an encased soil column, such as might be had under test conditions, a soil similarly may be filled with water, or saturated, and, by sealing in with water surfaces, may be forced to function as a saturated system.

Conditions of saturation are not ordinarily present in downward gravitational flow under field conditions, because of the interconnected capillary system of pores that is characteristic of soils. Air may enter a soil column *in situ* freely in response to pressure differentials. The behavior of a soil in the field is approximated the more closely by the behavior of an unencased or open soil column.

An essentially open soil column supported by a perforated tube is diagrammed in Fig. 3. The column is shown in magnified vertical section. Conditions of flow are assumed to be established throughout the column. As in cases previously discussed, pressure at the outlet is zero and tension develops throughout the column. In the present case, however, the walls are not rigid and impermeable but consist in part (in effect, wholly) of flexible air-water interfaces that tend to retreat under the influence of the differential between the internal tension of the system and the pressure of the outside atmosphere. In opposition, capillary forces tend to draw water into all the interstices of the soil pore system and maintain the air-water interfaces at the surface of the column. The balancing of these forces determines what capillaries remain filled with water and, therefore, effective in maintaining flow.

Effect of Capillarity on Gravitational Flow. The height, h, to which a liquid will rise by capillarity against the force of gravity, g, is expressed frequently by the equation $h = 2t/dgr$, where t is the surface tension, d is the density of the liquid, and r is the radius of the capillary. For water the approximation can be given as $h = 0.15/r$, and we can write equally logically that $-P = 0.15/r$, for, obviously, rise in the capillary ceases when tension below the meniscus balances the force that causes the rise. Whenever the value of the $-P$ that is induced by flow exceeds the value of $-P$ as defined above for any particular capillary in an open soil column, the interface retreats and the cross-section of voids or pore space through which flow takes place is thereby reduced. The equation above indicates that the larger capillaries are the first to empty, and the gradient of $-P$ in Fig. 2 indicates that the number of capillaries emptied is larger at the top of the column.

Saturation and Gravitational Flow. Some concept can now be formed of the degrees of saturation that may exist when water flows through an open column of uniform soil. If the voids of the soil consist wholly of fine pores or capillaries, and the velocity of gravitational flow is correspondingly low, then a condition of saturation may occur; that is, all the pores tend to become filled with water, even though some slight tension exists in the system. Saturation may not be complete, because soils normally retain some occluded air when wetted.

Conversely, a more permeable soil column, having an appreciable distribution of pore sizes, is never fully saturated when air has access to the system, except for a shallow surface layer and at the base of the soil column, where $P = 0$. The degree of unsaturation as tensions increase up the column is intricately related to pore size distributions, but it is not illogical to visualize the volume of voids actually carrying water as a truncated cone.

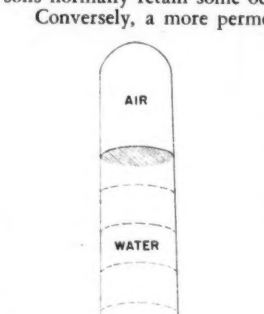

Fig. 4 Conditions for tension in a static system

When flow takes place in a cone-shaped tube, velocity, and therefore tension, increases toward the narrowest part of the tube, in accordance with Bernouilli's equation. This circumstance should increase somewhat the gradient of tension in an open as compared with a sealed soil column.

Tension in a Static System. The conditions of tension that have been described relate to a dynamic system of flow and are based on the assumption that water at zero pressure is continuously available at the top of the soil column. If the supply is cut off, free water at the surface disappears, but drainage of water from the column may continue for some time. Ultimately drainage ceases, essentially, and the system becomes static. Tension in a static system is illustrated in Fig. 4, and can be related to soil conditions.

Fig. 4 is a diagram of an inverted tube partly filled with water and covered at the mouth with a fine mesh screen. When the tube is first inverted, water flows through the screen; but equilibrium is soon established. At equilibrium, the height at which the liquid is supported becomes a measure of the difference between the pressure inside and that outside the tube. Capillarity at the screen merely makes the demonstration easy to perform, by allowing a deviation from the exact plane of equilibrium.

Pressure at the bottom of the tube is in equilibrium with that of the atmosphere, and therefore equal to it. Pressure at the top of the tube is less than this by the weight of a unit column of water, or dgh. When atmospheric pressure is taken as the zero datum line, pressure can be expressed negatively as tension, $-P = dgh$.

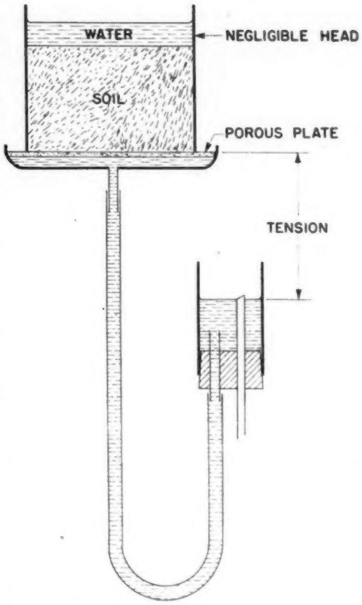

Fig. 5 Diagram of tension plate apparatus

Note that this equation expressed also the tension that results from flow, when the forces of friction were discounted. It follows that in a soil column under conditions of either free flow or drainage, the gradient of tensions that the system seeks to establish can be represented by the single line E in Fig. 2. The broken lines in this figure represent the changing gradients of tension that are to be expected in sequence in the draining of a short column of uniform soil.

Limit of Tensions Produced by Drainage. The value of $-P$ in the equation given above usually is limited to a maximum value by the nature of the forces that oppose gravitation. Thus the absolute height or tension at which water can be supported may be limited to a pressure of one atmosphere (Fig. 4), but this limitation does not apply to soils. Tensions much greater than one atmosphere of negative pressure characterize the lower values of soil moisture. However, these tensions are never reached as a result of gravitational drainage.

In Fig. 4 the pressure difference that is caused by the weight per unit area of a column of water is maintained because of the impermeability and rigidity of the walls of the tube. In soils the walls of the volume of voids occupied by water are either soil-water interfaces or (as pointed out previously) elastic air-water interfaces. The pressure difference in soils that is caused by the water column is maintained by capillarity. Consequently, if it is a fact that tension greater than that produced by drainage can exist in continuous films in soils, then the sole limit to the value of $-P$ that can be developed by gravitational forces is related to the friction of the soil system.

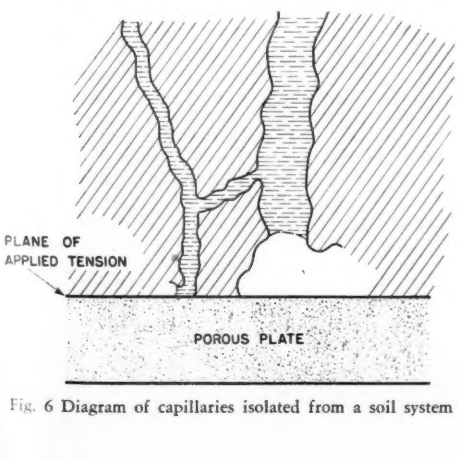

Fig. 6 Diagram of capillaries isolated from a soil system

Consider a soil column of infinite length. Drainage of the column progresses from the larger capillaries to the smaller. Tensions increase as indicated in Fig. 2, and, with increases in tension, smaller and smaller capillaries are drained. At the highest tension, water remains only in the smallest capillaries or as films on the surfaces of the soil grains. In such a system of capillaries and films, the change in tension per unit length in the upper part of the soil column becomes inadequate to overcome frictional resistance and flow ceases, essentially. What is known of the nature of fluid friction indicates that flow becomes negligible rather than ceasing entirely.

As flow ceases in the upper part of the soil column, the maximum tension that results from gravity is induced, and tension gradients in that part of the system tend to disappear. At this point the moisture content of the soil may be said to have reached field capacity, in so far as this function is governed by gravitational flow. The field capacity of a soil frequently approximates its moisture equivalent, which is accepted generally as representing a tension of about 500 cm of water.

Effect of Additive Tension on Gravitational Flow. Gravitational flow results in tensions of a low order in soils under equilibrium conditions. Greater tensions characterize partially drained and drier soils. The entry of water and the conditions of its passage through such soils are governed by the extent to which the forces of tension and gravitation are additive in effect. Examination of the effects of tension on gravitational flow in soil columns is made difficult by the changing conditions of tension that are encountered.

Fig. 5 presents a simplification of the conditions of tension, in that a stable tension can be applied at a fixed plane to the soil column. A cylinder that contains a column of soil rests on a porous plate. Contact between the plate and soil is assumed. A constant tension is maintained at the plane of the plate by a hanging water column. Tension at the plate can be adjusted by changing the effective length of the water column. The ordinary conditions for gravitational flow are established when tension at the plate is maintained at zero. A known tension can then be applied at the plane of the plate, and the results on flow can be noted.

The results obtained will depend on whether the plate and soil column constitute an open or a sealed system of pores. If the system is sealed, the effect of tension at the plate can be transmitted through the column and Darcy's law applies, i.e., an increase in flow occurs that is proportional to the increase in head, within the limits of experimental error. If there is no seal between the wall of the cylinder and the surface of the tension plate, then air has access to the system at this plane, and the air-water interfaces retreat in accordance with principles that have been discussed. Flow through the larger capillaries is cut off at plate level and, in effect, flow to the plate continues only from smaller capillaries whose size limit is defined by the tension that is applied to the plate. (It is assumed that the transmission capacity, per unit area, of the plate exceeds that of any channel.) New conditions of equilibrium are established with respect to flow and tension, which can be discussed with reference to a simple system that consists of but two interconnected capillaries.

This system is diagrammed in Fig. 6. The larger capillary has broken contact with the plate, and the effect of plate tension is not transmitted directly to it. However, the larger capillary will continue to transmit water gravitationally, and the velocity of normal gravitational flow will be accelerated slightly to balance drainage losses if the tension transmitted through the interconnecting capillary is sufficient to produce a curvature of the meniscus that occupies the outlet of the larger capillary.

Tension is transmitted directly to the smaller capillary, and flow in this part of the system can be assumed to follow the principles enunciated by Darcy and Bernoulli; that is, flow in the smaller capillary, from its junction with the interconnecting capillary to the plate, will be proportional to the difference between the sums of the gravitational and tensional forces at these points. Effective head similarly governs flow in the capillary branches above the junction. However, if the two branches are considered as one part of a single system of flow, then the cross-sectional area increases above the junction, and tension and velocities in that part of the system are reduced, in accordance with Bernoulli's theorem. The tension that is transmitted through the smaller capillary is dissipated by drainage from the larger.

BEHAVIOR OF COMPLEX CAPILLARY SYSTEMS OF SOILS

The analysis of flow in this simple system suggests an explanation for the behavior of the more complex capillary systems of soils when both gravitational and tensional forces are present. When water penetrates dry (or moist) soils, flow into the system is accelerated by tension. In many cases, flow does not increase proportionately with increase in the tensions that are applied. Excess of flow over normal gravitational flow is the result chiefly of increase in flow from the smaller capillaries, and is greatest when the wetting front is in close proximity to the plane of water entry at the soil surface. As the wet front descends, flow is maintained in the smaller capillaries to an increasingly greater degree by drainage from the larger capillaries. High tensions and high gradients are present only in close proximity to the wet front. Water flows through the larger capillaries only in zones of proportionately low tension, and this flow is basically gravitational. As length of wetted column increases, flow becomes increasingly gravitational in character in the smaller capillaries in the upper part of the soil column. The end-point rate of water intake at the surface of an initially dry soil column is essentially that of gravitational flow even though the column terminates in dry soil.

The entry of air into unsealed systems involving both tension and gravitation has resulted in some cases in essentially gravitational rates of flow in core samples on the device shown in Fig. 5. Application of low tensions increases the rate of flow. When higher tensions are applied, air enters the system and a marked reduction in flow occurs. The effect may be assumed to be due in part to imperfect contact (point contacts) between the plate and the soil column, although contact was adequate for approximately normal rates of drainage to the full capacity of the tension plate.

In sealed soil systems, flow under tension and gravitation approaches gravitational flow as a limit as length of soil column increases, in accordance with Darcy's law, which has been expressed as $v=kh/L$. Let h' equal the gravitational head and h'' equal the tension applied, and we can write

$$v=k\left(\frac{h'+h''}{L}\right)=k\left(\frac{h'}{L}+\frac{h''}{L}\right)$$

and, since in gravitational flow h' is always equal to L,

$$v=k\left(\frac{L}{L}+\frac{h''}{L}\right)=k\left(1+\frac{h''}{L}\right)$$

The value of h'' remains constant while L increases, so that the expression h''/L approaches zero as a limit, at which point $v=k$, or gravitational flow.

The effects of swelling, clay migration, and leaching purposely have been omitted from this discussion.

Discussion by T. W. Bendixen

I BELIEVE the foregoing paper by Mr. Slater adds a previously missing chapter to the literature on the movement of water through soils. The concepts and explanations have been presented on such a level that they can be understood by one having little knowledge of mathematics and physics. In places, the explanations are highly theoretical. In general, however, they should help in analysis and understanding of many of our hydrologic problems in soils where gravitational forces, as well as capillary forces, have an important influence on flow of water. Specifically, they may aid in analysis and understanding of results of lysimeter experiments. With an understanding of the explanations given by Slater, some of the findings from lysimeter studies might have been predicted.

The uncertainty of the true quantitative value of percolation from lysimeters has been recognized for some time[*][†]. On the basis of Slater's explanations, percolation from a lysimeter might be expected to be less than percolation through the same soil in a normal profile.

Lysimeters can be classified into two groups according to the relation of the lysimeter soil to the surrounding soil: (1) the Ebermeyer or Russian type and (2) the soil-block type. The first type is merely an intercepting funnel inserted into the natural soil at the desired depth, with no lateral separation of the lysimeter soil from the adjacent soil. In the second type, the lysimeter soil is completely separated from the adjacent soil and supported on a permeable plate. The soil-block lysimeter may contain undisturbed soil or may be filled artificially.

TENDENCY OF WATER FLOW IN RUSSIAN LYSIMETER

In the Russian-type lysimeter, there is a tendency for water to flow around the intercepting funnel instead of into it. In order for water to flow into the funnel, the pressure or tension at the plane just above the top of the funnel must be zero. However, if the wet zone through which water is moving downward extends below the lysimeter outlet, the funnel will be completely surrounded by water under tension, since, as Slater has explained, the flow of water even through a wet soil takes place under tension or negative pressure. Now, as the tension in the water immediately above the funnel approaches zero, a gradient is created between that water and the water in the adjacent soil. The water above then tends to move toward the area of higher tension, outward from the intercepting funnel. Thus, the measured quantity of water passing into the funnel may be less than the quantity passing the same plane in a normal profile, even during periods when surplus moisture is available for percolation.

The amount of water measured by the Russian-type lysimeter as being drained from the soil after saturated flow ceases also is likely to be less than the actual amount drained from the same depth of soil in a normal profile. During this draining period, the same tendency for the water to by-pass the funnel will be operative, since even higher tension gradients are present in the static system.

The soil-block lysimeter, also, may be expected to yield a smaller amount of percolate than the same soil completely undisturbed, particularly when the depth of soil in the lysimeter is considerably shallower than the normal profile. In the first place, in order for water to flow from the lysimeter, the resistance due to surface tension at the soil-air interface must be overcome. This resistance does not have to be overcome in the normal profile, which should allow the water to percolate through it at a somewhat faster rate. Actually, the rate through adjacent normal soil may be increased, owing to additive tension, if the wet zone through which water is flowing terminates in a drier zone. The effect of the additive ten-

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*Joffe, J. S. Lysimeter studies: I. Moisture percolation through the soil profile. Soil Sci., 34:123-143, 1932.

†Kohnke, Helmut, Dreibelbis, F. R., and Davidson, J. M. A survey and discussion of lysimeters and a bibliography on their construction and performance. USDA Misc. Pub. 372, 1940.

sion from the drier soil on the rate of water movement through the profile as a whole tends to become less, as pointed out by Slater, when the wetted column becomes longer.

After saturated flow ceases and the soils begin to drain, the soil-block lysimeter can be expected to yield a smaller amount of water than a similar depth of soil in a normal profile. In this case, the normal soil develops higher static tensions than the lysimeter soil, owing to the increased length of wetted column, and consequently more water will drain from the normal soil.

This discussion is not intended to be a criticism of lysimeters. The faults pointed out have been widely recognized, and corrective procedures have been developed‡. It is merely an attempt to show how the explanations given by Mr. Slater apply to a practical problem.

‡Wallihan, E. F. An improvement in lysimeter design. Jour. Amer. Soc. Agron. 32:395-404, 1940.

Discussion by R. E. Uhland

As Mr. Slater points out in his paper, the movement of water in soils is of interest to many technical workers and is of great importance to agriculture. The movement of water within the soil is seldom governed by the single force of gravity. Its downward movement is usually the result of the combined forces of gravitation and capillarity and is quite involved.

I shall limit my comments to a few of the assumptions made by the author, since I am sure that Dr. Richards will give full consideration to the completeness and correctness of the mathematical discussion.

In the first place, it is stated that "the flow of water through a uniform saturated soil is analogous in most respects to the flow of water by gravity through a vertical pipe of uniform diameter." Such a comparison does not seem valid because, even within a uniform soil, the soil pores are neither straight nor uniform in diameter. The implication in this paper is that friction as a factor in the movement of water in a uniform soil is of no great importance, which obviously is not the case. In the flow of water through tubes of soil-pore size, skin friction is of much greater importance than a reader would infer from the author's discussion.

Some soils allow water to permeate them so slowly that it is very difficult, or almost impossible, to satisfactorily drain them. Other soils may allow water to pass through them so rapidly that they retain little moisture and are usually classed as droughty. Still other soils, especially when they are poorly managed, may allow water to permeate the surface so slowly that runoff and erosion are excessive. Within a given soil profile, we may have horizons of varying depths which fill the description of many of the cases listed.

In Fig. 1 it will be noted that the straight-edged pipe is fitted into the bottom of the tank so that the top of the pipe is just flush with the inside bottom of the tank. This causes the stream of water entering the pipe to contract until its area, according to Angus§, is almost 62 per cent of that of the orifice, which means that the diameter of the stream is only 79 per cent of that of the opening. This stream bears the classical name of "vena contracta"—or contracted vein—and has been the subject of many studies and experiments. It has been found that the diameter of the vein is reached at a distance of about half the orifice diameter away from the face of it, and the stream then remains uniform in size until the air resistance breaks it up. Obviously this decrease in area produces an increase in velocity which likely accounts for the negative pressure referred to by the author as tension on the manometer that was located near the top of the tube.

R. E. UHLAND is research specialist, Soil Conservation Service, U. S. Department of Agriculture.

§Angus, Robert W. Hydraulics for the Practical Water-Works Man (seventh of a series of articles on design of discharge openings in tanks and reservoirs. Water and Sewage Works, vol. 94, no. 2, February, 1947, pp. 69-72.

Discussion by S. J. Richards

A REVIEW of the subject of water movement in soils is an ambitious undertaking. Mr. Slater is to be commended for his effort. Since an invitation to discuss a paper implies that both favorable comments and criticisms are in order, the following will contain some of both.

The use of an open pipe to develop some of the basic ideas of water movement in soils is entirely justified. Water flows in soils in response to pressure gradients and gravity just as it does in pipes. The fact that water occurs in soils under pressures less than atmospheric (such pressures are called tensions) is well illustrated by Fig. 1. In the text dealing with Fig. 1, however, Mr. Slater has failed to realize that Newton's third law of motion helps to govern the motion of the water in the pipe. In the discussion it is pointed out that the water in the lower end of the pipe accelerates the water in the top end of the pipe so that all the water has the same velocity. Newton's law requires that the water in the upper end of the pipe exert a force upward on the water in the lower end. This latter water then is not "freely falling" even though friction is neglected. The velocity at the pipe outlet would then be *less* than gt, or *less* than $\sqrt{2gh}$. It must therefore be concluded that the tension at the top of the pipe will be something less than dgh, since its value is calculated from the outlet velocity. This is fortunate because if the tension at the top of the pipe were dgh, then static equilibrium would exist, as is shown in the discussion of Fig. 4, and water would not flow out of the bottom of the pipe.

Bernoulli's theorem is a convenient relation to use in the example chosen. It should be remembered, however, that the kinetic energy term is negligibly small and is usually neglected in any case dealing with soil moisture.

In his definition of Darcy's law, Mr. Slater has omitted gravitation. The way he has chosen to define h makes the law applicable only for the special case of horizontal flow. If properly stated, h in the equation should be the difference in hydraulic head at the two points on the same stream line from which L is measured. The hydraulic gradient is then h/L.

It should be noted that Darcy's law is meant to be applicable only in the case of saturated flow. A relation that looks like Darcy's law has been used to express the results of experiments on the unsaturated or capillary flow of water through soils. Under these conditions the ratio of flow to hydraulic gradient is a widely varying function of the soil moisture tension. This ratio, called capillary conductivity, has been shown to decrease to less than one-hundredth of its value as soil moisture tension increased from 10 to 250 cm of water. Figs. 3 and 6 in Slater's paper show pictorially why this occurs. As the tension increases the moisture content of the soil decreases and leaves a smaller effective space to transmit water.

The statements in the paper concerning the influence of friction on the flow of water are misleading. Friction forces are everywhere zero when flow ceases; hence they play no part in static equilibrium conditions. Equilibrium occurs when a tension gradient develops, as illustrated in Fig. 4, which balances the pull of gravity on soil water, or in other words the hydraulic gradient becomes zero and there is no longer a net water-moving force. Resistance determines the amount of flow when the water-moving force is not zero and is evaluated in terms of the permeability or conductivity of a soil column.

The equipment shown in Fig. 5 is typical of many experiments dealing with unsaturated flow of water in soils. Some error is involved, however, if it is assumed that all of the tension indicated in the figure is applied to the water at the base of the soil column. While flow is occurring some of the tension is lost as a result of the resistance to flow in the porous plate. Except for this error, Slater shows how gravitation and tension both contribute to the water-moving force in the particular example chosen.

Some simple illustrations will show how hydraulic gradient may be used to account for the effects of gravitation and pressure or tension gradients in causing water to flow. In the ac-

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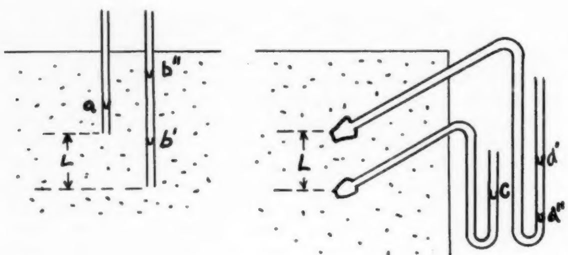


The case for saturated flow is shown at the left, and for unsaturated flow at the right

companying sketch the case of saturated flow is shown at the left. Two open-end piezometer tubes are placed in the soil. The relative position at which water stands in the two tubes is a measure of the difference in hydraulic head. This difference divided by L is the hydraulic gradient used in the Darcy equation. If water stands at b' below a, flow is downward; or if water stands at b'' above a, flow is upward.

At the right in the sketch similar relationships for the case of an unsaturated soil are shown. Here water manometers connected to tensiometer cups replace the piezometer tubes. If water stands at d' above c, flow is downward; or if water stands at d'' below c, flow is upward. The total water-moving gradient is the difference in the levels in the two manometers divided by L. For convenience in working above the soil surface, mercury manometers or dial vacuum gauges are used, but, if tension is measured at two levels, the average hydraulic gradient may be calculated.

Closure of Discussion by C. S. Slater

SOME of the comments made by Uhland, Richards, and Bendixen on my discussion of the flow of water through soils are indicative of the abbreviated character of that discussion. Bendixen extends the scope of the paper by showing how basic physical laws may apply to a specific case. Uhland notes that the *vena contracta* is not discussed in connection with Fig. 1, and Richards points out that no consideration is given to the loss of tension that would occur as the result of resistance to flow in the porous plate of Fig. 5. However, these are omissions rather than errors. In order to be brief, it was necessary for me to assume that persons reading this paper would have a reasonably sound foundation in general physics, and would supplement from their own information the principles and theorems on which the discussion is based.

Exception may be taken to other comments made either by Uhland or Richards. This is illustrated in their divergent points of view with respect to my use of an open pipe to develop some of the basic ideas of water movement in soils, and my treatment of the part played by friction in governing the flow of water through soils. I feel, however, that a discussion of all the points raised by these reviewers would not be greatly advantageous to the reader, and on that basis prefer to let the case rest for the most part on my original exposition.

Similarly, I feel that I should meet Richards' criticism of my discussion of Fig. 1. He states that outlet velocity must be something less than $\sqrt{2gh}$, and so concludes that the tension at the top of the pipe must be something less than dgh. The difficulty appears to lie in some lack of clarity in my discussion of outlet velocity.

My contention that outlet velocity in a frictionless system is equal to that of a freely falling body is based on the axiom that energy can be neither created nor destroyed. Basically, it is a restatement of Torricelli's theorem. I tried to simplify discussion by assuming an atmospheric pressure of zero. On that basis each unit of water at the top of the pipe has an energy of position only. This is equal to mgh. Since a frictionless system is specified, no energy is lost in transit, irrespective of any distribution of energy within the pipe in the form of velocity, position, pressure, or tension. Therefore, the energy of each unit of water as it leaves the pipe also must be equal to mgh. At the bottom of the pipe, however, all energy of position has been translated into an energy of velocity, which for each unit of water is $\frac{1}{2}mv^2$. The value of v can be expressed in terms of g and h

$$mgh = \tfrac{1}{2}mv^2, \text{ or } v = \sqrt{2gh}$$

Richards' statement that static equilibrium would exist if tension at the top of the pipe had its full value of dgh is meaningless. True, static equilibrium does require a tension of dgh under the conditions illustrated in Fig. 4, where in contrast to Fig. 1, the free water source at the top of the column is eliminated. In the system that involves flow (Fig. 1) the energy of flow must be considered. Forms of energy, not merely the forces of tension or pressure, must be kept in balance in order to maintain the *status quo* of any system, static or kinetic. The classical example of flow of water from zones of low to zones of high pressure is the Venturi tube.

Unit Operations

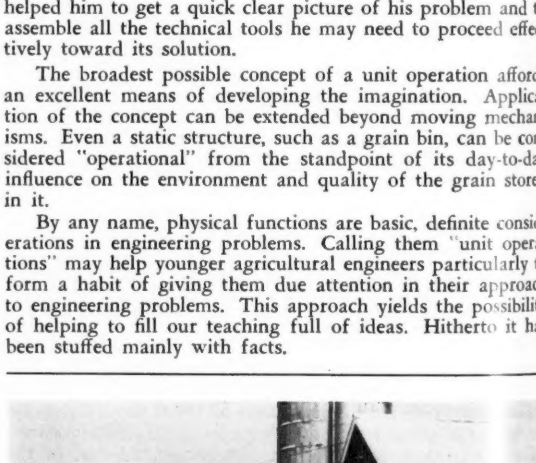
(Continued from page 116)

unfamiliar ground, can proceed with some efficiency to determine, the present state of the applicable art and science. The information may be partly or wholly available in engineering handbooks, in other technical literature, in manufacturers' data books, in comparable applications in other fields, or in the minds of more experienced men in the particular field concerned.

When he gets this fairly complete and detailed picture of a functional problem, and of known engineering applications to serve similar functions, possible solutions to the problem will be suggested to him. These solutions may be ready made and tested in some other field, and available for use with minimum modification; or they may be new and experimental. The main point is that the unit operations viewpoint has helped him to get a quick clear picture of his problem and to assemble all the technical tools he may need to proceed effectively toward its solution.

The broadest possible concept of a unit operation affords an excellent means of developing the imagination. Application of the concept can be extended beyond moving mechanisms. Even a static structure, such as a grain bin, can be considered "operational" from the standpoint of its day-to-day influence on the environment and quality of the grain stored in it.

By any name, physical functions are basic, definite considerations in engineering problems. Calling them "unit operations" may help younger agricultural engineers particularly to form a habit of giving them due attention in their approach to engineering problems. This approach yields the possibility of helping to fill our teaching full of ideas. Hitherto it has been stuffed mainly with facts.



J. I. Case tractor and trailer knee-deep in March on the 600-acre Blake farm in Porter County, Indiana

RESEARCH NOTES

A.S.A.E. members and friends are invited to supply, for publication under this heading, brief news notes and reports on research activities of special agricultural engineering interest, whether of federal or state agencies or of manufacturing and service organizations. This may include announcements of new projects, concise progress reports giving new and timely data, etc. Address: Editor, AGRICULTURAL ENGINEERING, St. Joseph, Mich.

USDA Notes on Prefabrication, Cotton Insulation, Mechanization, and Kitchens

Prefabrication. Agricultural engineers will be interested in recent work of the USDA Forest Products' Laboratory at Madison, Wis., on new wood products and construction methods adapted to them. The Laboratory has prepared for the federal Housing and Home Finance Agency an illustrated manual on the use of wood for prefabricated housing. Information presented is based on Laboratory research and results of a nation-wide survey of prefabricated house manufacturers. Subjects covered include basic information on wood, plywood, laminated wood, modified woods, fiberboards, plastics, and sandwich materials; strength of materials; seasoning and storage; machining of wood and other wood-base materials; gluing of wood, plywood, plastics, and sandwich construction; joints and fastenings; house design; fabrication procedures, and repair techniques.

Nailing. Also prepared by the Laboratory for the Housing and Home Finance Agency is a bulletin, titled "Technique of House Nailing," issued November, 1947. Though nailing is one of the most commonly used methods of fastening for wood, very few data are available on nailing practices. Recognizing that great numbers of houses were to be erected and knowing the advantages that result from the use of good nailing practice in house construction, the agencies collaborated on this extremely useful handbook. Most of the information is presented in 50 line drawings covering all important construction details.

Laminating. The Forest Products Laboratory has also recently completed a manual on the subject of laminating structural timber products by gluing. The contents of the manual are based on the experience gained during the war and since in the use of glues for building up large laminated beams from relatively thin boards. It covers the properties of glues suitable for laminating, the techniques of laminating, and recommendations for inspecting and testing laminated products.

Crate Design. Of related interest are two other announcements of research accomplishments by the Forest Products Laboratory. Although the Laboratory had done extensive work on the strength and design of open crates for relatively small and light articles, no scientific information was available for large open crates designed to carry heavy loads. Recent testing and development work has made it possible to provide designs for loads up to 30,000 pounds net. A distinctly new type of construction was evolved employing prefabricated panels in which diagonal braces are placed on both faces of the frame members. The diagonals on one face slope in the opposite direction from those on the other face.

Corrugating Boards. The Laboratory has also demonstrated that corrugating boards can be made successfully from woodworking wastes such as those from box plants and furniture and veneer mills. The pulps for the boards were made from the three wastes employing two different chemical pulping agents (neutral sulfite and soda ash). There was little difference in properties of the pulp from the two processes. However, the box plant wastes produced the strongest pulps in the highest yield (81 per cent of original wood) and the veneer waste the weakest pulp (by roughly 25 per cent) in the lowest yield (71 per cent).

Wood Coating. Other achievements along the same general line have ben contributed by the USDA Regional Research Laboratories. One is a singularly durable coating for wood, highly resistant to wear, hot oils, and heat, which has been developed from ordinary table sugar, or sucrose, by P. L. Nichols, Jr., and E. Yanovsky, of the Eastern Regional Research Laboratory, Wyndmoor, Pa. As prepared it is a heavy light-yellow liquid which, when exposed to air or oxygen, particularly at elevated temperatures, increases in density and viscosity and finally hardens into an insoluble, infusible, transparent rosin. Properly cured films of it are insoluble in all organic solvents so far tested. The coating possesses high gloss and extreme hardness, yet sufficient flexibility to expand its usefulness. Its transparency suggests use as an adhesive for glass. The coating and impregnation of paper, textiles, and other materials for water and greaseproofing and increase of their tensile strength are distinct possibilities.

Plywood Adhesive. At the Northern Regional Research Laboratory, Peoria, Ill., a new waterproof plywood adhesive having considerable binding strength has been developed by scientists of the Bureau of Agricultural and Industrial Chemistry. It is made by combining solvent-extracted soybean meal freed of its water-soluble constituents, or corn gluten, with phenolic resin in the intermediate or water-soluble form. A commercial trial demonstrated that excellent plywood could be fabricated with such a glue, which becomes insoluble on setting. A plywood manufacturer made practical use of this discovery and has consumed large quantities of a commercial brand of soybean meal in making waterproof plywood. A manufacturer of soybean meal offered to supply a large amount of the proper quality to companies interested in the use of a soybean-modified, phenolic-resin plywood adhesive. Since the new adhesive costs less than other waterproof adhesives and results in plywood suitable for use as such or for use as concrete-pouring forms in building houses and other structures, it should help to reduce construction costs on farms and elsewhere.

Cotton Insulation. The introduction of cotton as an insulating material has had the attention of the cotton branch of the USDA Production and Marketing Administration for several years. This new application of flame-repellent principles and determination of the most economically effective densities have opened the way for cotton's use in this field. In its preparation for this use, cotton is slightly fluffed, run through baths of chemical salts, dried, and made into batts or blankets of insulation. Thereafter the cotton will withstand a blowtorch flame of 1800 F, and have a density of about 0.06 pound per board foot. Thicknesses (from ¾ to 4 in or more) and widths can be varied to meet use requirements. The product has a very high insulating value and is suitable for use in homes, in farm and industrial structures, and in other places where insulation serves a useful purpose. This high-quality product, made from the lower grades and shorter staples of cotton, is being manufactured and sold by eight companies with plants in California, Connecticut, Michigan, New York, North Carolina, Texas, and Wisconsin.

Farm Mechanization. Technological developments have had a profound effect on American agriculture in the last 100 years. One farm worker in 1945 produced enough agricultural products to support himself and 13½ other persons. In 1920 one farm worker supported himself and 9 others, and in 1820 himself and 3½ others. Each man-hour of farm labor meant 44 per cent more gross production in 1945 than in 1917-21. About half the savings in hours per unit of production resulted from mechanization. These and many other developments in the last century due to mechanization are the subject of a new publication of the Bureau of Agricultural Economics. Emphasis is given to the effect of the developments in the last 25 years on the volume of food production, labor requirements, farm employment, and efficiency in production.

Model Farm Kitchen. A farm kitchen planned so two women may work comfortably and conveniently with minimum walking, stooping, lifting, and stretching has been designed and built by USDA housing and household equipment specialists under the direction of Miss Lenore Sater of the Bureau of Human Nutrition and Home Economics. This is the first kitchen ever completely built in the Department. Although it is planned primarily for the farm home, it fits other types of households in most respects.

Some of the basic principles used in planning this room and their advantages are explained by Miss Sater:

The unbroken U arrangement of equipment around three adjoining walls of the room was chosen because it forms a compact work center through which household traffic does not pass and interrupt work. It also makes possible a convenient dining corner outside the work area.

Work moves from right to left, the direction that suits right-handed workers. Counter space is adequate for each job done there. Ample storage space is planned to accompany the various jobs carried on in a farm kitchen where there is a separate laundry and workroom. All supplies and equipment are stored within comfortable reach of the place where they are first used. Storage also is arranged so that the articles used most are easy to see and within closest reach. All cabinets suit the different articles they hold in size and shape.

Special features of this streamlined farm kitchen include the following:

Double-deck flour bins: A small bin just above the mixing center where the flour is used replaces the familiar less convenient flour canister. Just above is a big reserve flour bin which quickly feeds flour into the small bin when a metal shutter is opened.

A convenient, non-stoop garbage disposal arrangement, planned especially for farm use: An oblong opening cut in one sink counter permits vegetables to be peeled and plates scraped directly into a big pail just under the counter. This saves the usual stooping to empty garbage into a pail at floor level. The filled pail may be removed through an opening in the outside wall of the kitchen for convenience in carrying it to farm animals. When empty the pail is taken out for washing through the cabinet door in the kitchen. The opening in the counter, the lid which lifts out and the entire inside of the cupboard holding the pail are metal-lined for cleanliness.

Non-slide, pull-out boards: When pulled out these boards automatically lock into place. When a simple gravity-stop underneath is released, the board pushes back under the counter.

Revolving corner cupboards: These "lazy Susan" circular shelves turn on a center pole and are built in corners above and below counter levels. Corner space in kitchens often is wasted because it is so hard to reach in the usual straight cabinets. The revolving shelves make for convenient and ample storage at this location, especially of large utensils, and they save both stooping and stretching.

NEWS SECTION

Southwest Section to Meet at Texarkana

THE Southwest Section of the American Society of Agricultural Engineers will hold its yearly meeting at the Grim Hotel at Texarkana, Texas, March 26 and 27. An attractive program has been arranged, which will be of outstanding interest to agricultural engineers in other than the Section area.

The forenoon program on March 26 will include four papers: One on rice drying by Xzin McNeal, University of Arkansas; another on farm housing by W. S. Allen, A. & M. College of Texas; one on the long-range picture of soil utility, by Roy E. Hayman, Public Service Co. of Oklahoma, and another on drying peanuts by J. W. Sorenson, Jr., Texas Agricultural Experiment Station.

The afternoon program for the same day will open with a paper by Charles R. Mayerhoeffer, U. S. Bureau of Reclamation, on some phases of the valley gravity project on the Rio Grande River, and this will be followed by a paper by D. L. Jones of the Lubbock (Tex.) Experiment Station on cotton mechanization developments on the high plains of Texas. There will be a panel discussion on rural electrification at this session participated in by Ed Hodge, Louisiana Power & Light Co.; Russ Mauney, Arkansas Power & Light Co.; R. R. Jones, Louisiana State University, and Lamoyne Goodwin, Gulf State Power Co. A final number on this program will be an address by George A. Rietz, President of the A.S.A.E., on opportunities for agricultural engineers.

The Section dinner will be held the evening of the same day, with Kyle Engler, chairman of the Southwest Section, as master of ceremonies. A feature of the dinner will be an address by Dr. Lewis W. Jones, president of the University of Arkansas.

The forenoon program of March 27 will open with a paper on the application of anhydrous ammonia by Lelend D. Morgan, Louisiana State University, followed by one on electric milk pasteurizers for home use, by J. P. Hollingworth of the A. & M. College of Texas. W. J. Oates, Oklahoma A. & M. College, will present a paper on the cotton mechanization program in Oklahoma, and will be followed by I. M. Leimbrook, branch manager of the International Harvester Co. at Freeport, La., on new developments in farm machinery. A business session of the Section, including the election of officers, will close the program.

Officers of the Section this past year, in addition to Mr. Engler, the chairman, are Vice-Chairman R. H. S. Henderson, assistant branch manager at Dallas of Allis-Chalmers Mfg. Co., and H. T. Barr, Louisiana Agricultural Experiment Station, Secretary-Treasurer. Program chairman for the meeting at Texarkana is A. H. Gray, Jr., Southwest Gas & Electric Co.

Programs and other information about the meeting will be sent on request to Section officers, or to the headquarters of A.S.A.E. at St. Joseph, Michigan.

Chicago Contributes to Technical Conference

THE Chicago Section of the American Society of Agricultural Engineers, as an affiliated society of the Chicago Technical Societies' Council, will contribute to the program of a technical conference which C.T.S.C. is sponsoring in connection with its Chicago Production Show at the Stevens Hotel, March 22 to 24.

The Chicago Section's participation consists of a two-hour panel discussion of the subject "Increased Food Production in America" which will be held from 4 to 6 p.m., Monday, March 22, at the Stevens Hotel.

A.A.A.S. Plans Centennial Celebration

"ONE World of Science" is the announced keynote for a centennial celebration meeting of the American Association for the Advancement of Science, to be held in Washington, D. C., September 13 to 17, 1948. The A.A.A.S. was founded in September, 1948.

The American Society of Agricultural Engineers is one of the organization members of the A.A.A.S., and some individual members of A.S.A.E. are also individual members of A.A.A.S.

According to the announced plan, mornings will be devoted to concurrent technical symposia in various scientific fields of great current interest and importance. Afternoons are to be free of formal sessions to permit those present to visit the numerous scientific and cultural institutions in and around Washington. Evening programs will feature nontechnical broad surveys of current progress in important fields of science.

More than forty educational and cultural institutions in the Washington area are helping with local preparations with a view to providing opportunity for every visiting scientist to make the most of his visit to Washington.

A.S.A.E. Meetings Calendar

March 26 and 27 — SOUTHWEST SECTION, Grim Hotel, Texarkana, Texas.

April 29 to May 1 — MISSOURI SECTION, Hotel Muehlebach, Kansas City, Mo.

May 3 — CHICAGO SECTION, Builders' Club, Chicago.

May 6 — MICHIGAN AREA SECTION, Michigan State College, East Lansing.

May 14-15 — VIRGINIA SECTION, Hotel Roanoke, Roanoke, Va.

June 21 to 24 — ANNUAL MEETING, Multnomah Hotel, Portland, Oregon.

September 7-10 — NORTH ATLANTIC SECTION, Ontario Agricultural College, Guelph, Ont., Canada.

October 21 and 22 — PACIFIC NORTHWEST SECTION, Columbia Gorge Hotel, Hood River, Ore.

December 13-15 — WINTER MEETING, Stevens Hotel, Chicago.

Southeast Section Elects Johnson

THE Southeast Section of the American Society of Agricultural Engineers elected as its new chairman for the coming year, Glenn I. Johnson, extension agricultural engineer, University of Georgia. The election took place at the yearly meeting of the Section held February 12 to 14 at Washington, D. C., in conjunction with the annual convention of the Association of Southern Agricultural Workers. Mr. Johnson succeeds Geo. B. Nutt, head, agricultural engineering department, Clemson Agricultural College, who has served the Section as chairman the past year.

Other officers elected are First Vice-Chairman, John W. Weaver, Jr., associate in agricultural engineering, North Carolina Experiment Station, and Second Vice-Chairman, Joe B. Richardson, assistant agricultural engineer, Clemson Agricultural College. Harry W. Dearing, Jr., agricultural engineer, Tennessee Coal, Iron and Railroad Co., was re-elected to the office of Secretary-Treasurer.

The Section headquarters during its meeting at Washington was at the Hamilton Hotel where all the sessions were held. There was a total registered attendance of 109 members and non-members of A.S.A.E., which included a large percentage of members in or near Washington.

A special ladies night meeting of the Washington (D.C.) Section of the Society was held on the evening of February 11 preceding the opening of the Southeast Section meeting, and the Washington Section also handled arrangements for the Southeast Section dinner meeting on February 13.

The Southeast Section program opened the forenoon of February 12 with a symposium on supplemental irrigation in the Southeast. The remainder of the session included a paper on irrigation requirements of soils, and another on Georgia's irrigation program, followed by the irrigation experiences of a Virginia market gardener.

The afternoon program of the same day included papers on fence post preservation, applications of steel to crop drying and storing, sweet potato propagation and storage, lightning protection for buildings, a dairy barn program, and a report on rural housing research.

The forenoon program of February 13 opened with an address on the basic requirements for agricultural engineering research by Dr. R. W. Trullinger, chief, Office of Experiment Stations, USDA, followed by an address by Dr. E. D. Smith, associate director of the Alabama Agricultural Experiment Station on the responsibilities of the agricultural engineer in Southeast agriculture. This in turn was followed by an interesting discussion of the agricultural engineer's responsibilities and opportunities under the Research and Marketing Act by one of the associate directors administering the Act.

The afternoon program of the same day consisted of a symposium on machinery and equipment designed to meet requirements of the Southeast by several company representatives. The symposium was summarized by Dr. M. L. Nichols, in charge of research, Soil Conservation Service, USDA.

The forenoon program of February 14 was devoted to a symposium on agricultural industries and services, and the afternoon and closing program of the meeting included a paper on curing of tobaccos of the Turkish type, and four papers on various phases of peanut production.

The closing paper on the program was one on the need for three-phase electric power on rural lines. *(News continued on page 128)*

NEWS SECTION

(Continued from page 126)

Bainer Heads Pacific Coast Section

AT THE yearly meeting of the Pacific Coast Section of the American Society of Agricultural Engineers held at the Yuma Air Base, Yuma, Arizona, February 6 and 7, Roy Bainer, head, agricultural engineering division, University of California, was elected the new chairman of the Section for the ensuing year.

George D. Clyde, chief, division of irrigation (research), Soil Conservation Service, USDA, was elected the new vice-chairman, and Walter W. Weir, drainage engineer, division of soils, University of California was reelected secretary-treasurer. The newly elected member of the Executive Committee is Clarence T. Rasmussen, chief engineer, Killefer Mfg. Corp. The new Nominating Committee elected at the meeting consists of Adrian St. J. Bowie (chairman), chief engineer, Bean-Cutler Division, Food Machinery Corp.; J. E. Christiansen, dean of engineering, Utah State Agricultural College, and J. P. Fairbank, professor of agricultural engineering, University of California.

A total of 80 members and friends of A.S.A.E. attended the meeting at which a very interesting program of papers was presented. Honor guest of the Section was George A. Rietz, president of A.S.A.E., who delivered one of the principal addresses of the meeting.

Michigan Area Section Winter Meeting

TRACTORS and tractor equipment were featured at the winter meeting of the Michigan Area Section of the American Society of Agricultural Engineers at Detroit, Mich., Saturday, February 14. The meeting was held at the Ethyl Corp. research laboratories. Approximately 125 attended, in spite of bad driving conditions, to make the meeting the biggest held by the Section to date.

In the morning session J. R. Mohlie, plant manager, Battle Creek Works, The Oliver Corp., reviewed the development of the farm tractor. W. R. Peterson, farm implement division, International Harvester Co., followed with development of implements for the farm tractor.

Members of the Ethyl Laboratories staff served as guides for a quick tour through the laboratory followed by a luncheon in the building.

During the lunch hour A. W. Farrall, head, agricultural engineering department, Michigan State College, reported on plans for dedicating the new agricultural engineering building there during the first week in May. He invited the Section to hold its spring meeting there as a part of the ceremonies. A motion to accept the invitation was passed after brief discussion.

Mr. Farrall also reminded the group that it will be host to the Annual Meeting of the A.S.A.E. at East Lansing in June, 1949, and he invited suggestions for preliminary planning and for attractions of Michigan and the adjoining areas, as well as meeting features, to be presented to those attending the annual meeting at Portland, Ore., in June, 1948.

A symposium on the place of the small tractor in Michigan agriculture, during the afternoon, completed the program. D. A. Milligan, production manager, Harry Ferguson, Inc., indicated that anything defined as a tractor should be capable of pulling at least one 14-inch plow. D. C. Heitshu, chief engineer, John Deere Harvester Works, emphasized design problems of operator comfort, control, and interchangeability of operating equipment to increase the value of the small tractor. W. J. Adams, Jr., chief engineer, Bolens Products Div., Food Machinery Corp., called attention to uses of smaller sizes of small tractors for small acreages and for supplementary power and special jobs in larger operations.

Western Farm Machinery Conference

AN AGRICULTURAL Engineering Conference was held at Davis, Calif., February 12 to 14, sponsored jointly by the agricultural engineering division, University of California, and the research committee of the Farm Equipment Institute.

The conference provided for an exchange of information and viewpoints on agricultural engineering in the West, between men in public service primarily concerned with technical possibilities, men in the farm equipment industry concerned with physical means, and farmers concerned with profitable applications of engineering principles and engineered equipment in farming operations.

A.S.A.E. members on the program included N. B. Akesson, Roy Bainer, J. P. Fairbank, C. E. Frudden, F. P. Hanson, M. R. Huberty, B. D. Moses, Osgood Murdock, C. T. Rasmussen, E. W. Tanquary and H. B. Walker. Robert A. Jones handled arrangements for the eastern delegation attending. Roy Bainer headed the California activities on behalf of the conference, and F. P. Hanson represented the research committee of the Farm Equipment Institute.

Major emphasis of the meeting was on research and the application of its results. Agricultural commodities given specific attention included livestock, cotton, sugar beets, truck crops, grapes, and deciduous fruits. From a special equipment and operations standpoint the program touched on pest control, mechanical cotton pickers, sugar beet harvesters, precision planting, and labor saving. Torque converters and hydraulic controls were presented as power equipment features increasing the users' mechanical advantage. Influences of electricity, irrigation, and other specific factors to progress in mechanization served to round out the picture of agricultural engineering in the West. Some of the newer approaches to problems of the area are reflected in such titles as "Designing Cotton Plants for Mechanization" and "The California Farm as a Proving Ground for Farm Machinery."

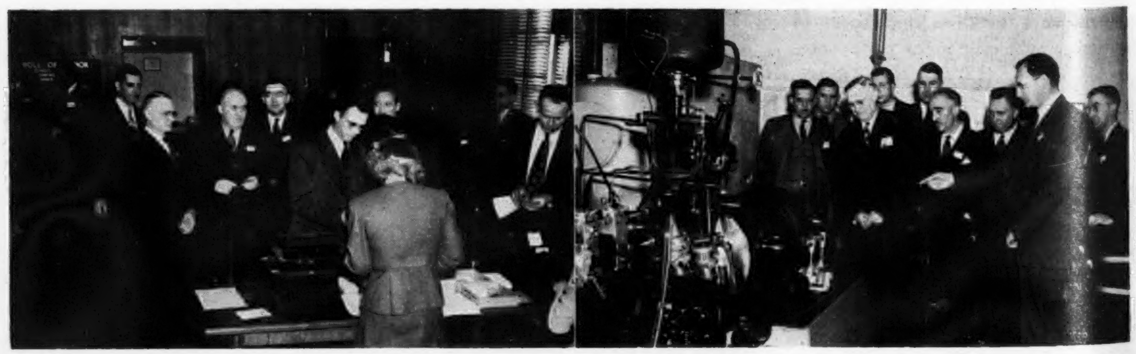
The eastern group of guests at the conference spent the preceding day touring plants of the Food Machinery Corp. at San Jose and other industrial and agricultural developments in the vicinity.

Agricultural Engineers Discuss Fumigation

SOIL fumigation equipment was discussed by three speakers before the Honolulu Agricultural Engineers' Club at the University of Hawaii's Agricultural Engineering Institute on Wednesday evening, January 28. Dr. Walter Carter of the Pineapple Research Institute, Robert Owen of the California Packing Corp., and E. H. Thomas of the Pacific Chemical and Fertilizer Co. were the speakers. Dr. Carter emphasized that injection of fumigants into the soil kills not only harmful nematodes and wireworms, but hundreds of other organisms both bad and good. The effect of the dead organisms as fertilizer, and the return of microscopic life to the fumigated soil, have effects that can only be determined by field trials for each crop and each type of soil.

Mr. Owen, who has designed successful mechanical fumigant injectors for the pineapple industry, pointed out that because the fumigants are both costly and destructive, it is important to apply exactly the right amount per acre. He also described humorously the manner in which the fumigants have sometimes dissolved parts of the machinery in a matter of minutes.

Hawaii has led the world in soil fumigation, according to Mr. Thomas. One large chemical manufacturer constructed a plant especially to make fumigants for Hawaii, but is now selling an increasing part of its output on the mainland and Hawaii is finding it hard to obtain adequate supplies. *(News continued on page 130)*



At A.S.A.E. Michigan Area Section meeting at Ethyl Corp. Research Laboratories, Detroit, February 14. *Left:* A. W. Farrall (hands folded), Michigan State College, with D. A. Milligan, Harry Ferguson, Inc., and Ralph A. Palmer, assistant secretary, A.S.A.E., to his left. Ethyl's Dan W. Guy (top of head showing) beyond registration clerk. *Right:* Chris Nyberg, The Oliver Corp. (in dark suit); to his left Section Chairman H. J. Gallagher, Consumers Power Co. Back of Gallagher, Section Secretary F. W. Peikert, Michigan State College (left), and J. R. Mohlie, The Oliver Corp. Ralph A. Palmer, extreme right. Others not identified

NEWS SECTION

(Continued from page 128)

Farm Electrification Institute Scheduled

THE ninth annual New England Farm Electrification Institute is to be held at the Hotel Mohican, New London, Conn., March 30 through April 2.

Subjects scheduled include ultrasonics, hay drying, power pole load centers, farm wiring inspection service, distribution channels for farm equipment, rural electric extension work, vocational agricultural activities in electrification, farm electrification research, safety in farm wiring, safeguards for continuity of farm service, and heavy-duty motors for farm service.

One evening session is planned as a round table providing an open forum on any and all subjects which may be brought up.

Daytime sessions on Thursday, April 1, are to be held at the University of Connecticut.

Tours of the U. S. Naval Submarine Base, Electric Boat Company, U. S. Coast Guard Academy, and the Connecticut College for Women will be available Friday afternoon, April 2, as the concluding feature of the Institute.

A.S.A.E. members on the tentative program are R. J. Bughee, L. C. Felder, E. W. Foss, G. M. Foulkrod, H. J. Gallagher, H. F. Gulvin, T. E. Hienton, R. E. Johnson, W. A. Junilla, M. S. Klinck, M. H. Lloyd, W. J. Rideout, F. L. Rimbach, H. N. Stapleton, and A. W. Turner.

Personals of A.S.A.E. Members

Jimmie G. Andros, who until recently was serving as a captain in the U. S. Army, is now employed as assistant professor and extension specialist in agricultural engineering at the University of Illinois.

Thomas W. Bendixen has resigned his position as engineer-in-charge of geotechnical research in the college of engineering at the University of Maryland, to accept appointment as extension specialist in soils and irrigation at the University of Arizona, Tucson.

Eugene I. Kirkland, formerly product development engineer for the National Milker Co., is now engaged as designing engineer on the V-2 rocket for General Electric Company's research and development service and is located at Fort Bliss, Texas.

Lester G. Kopp recently resigned as project engineer for Harry Ferguson, Inc., to accept a position as assistant chief engineer of the South Bend Works of The Oliver Corporation.

M. R. Lewis, until recently employed by the Bureau of Reclamation, U. S. Department of the Interior, at its office at Boise, Ida., was recently transferred to the Washington, D. C., office of the Bureau, where he is now chief of the Division of Irrigation Operations in the Branch of Operation and Maintenance of the Bureau.

William F. Lytle, who has recently received his master's degree in civil engineering at the University of Illinois, is now employed on the agricultural engineering staff of that institution, and will be engaged in research work in the field of soil and water conservation.

Kurt Nathan has completed his graduate work at Cornell University and resigned his position as teaching assistant in agricultural engineering, to accept an assistant professorship at the National Farm School and Junior College at Farm School, Pennsylvania.

(Continued on page 134)

New Literature

BUILDING BETTER FARM HOMES WITH CONCRETE. Portland Cement Association (33 W. Grand Ave., Chicago 10, Ill). Paper, 32 pages, 8½ x 11 inches, illustrated.

Brief digest of recommended methods for using Portland cement concrete in walls, insulation, subfloors, floors, footings, foundations, basements, roofs, stairways, and decorative items.

PROCEEDINGS OF THE INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS. No. 3-5, vol. IV (December, 1947), paper, pages 35-76, incl., 5½ x 8½ inches, 2s, 6d. (68 Victoria St., S.W. 1, London.

Subjects covered include wheels, tracks, and half-tracks; ploughs and ploughing; annual general meeting, June 1947; milking machines, and recent trends in farm engineering.

New Federal and State Bulletins

Devices for Measuring Rates and Amounts of Runoff Employed in Soil Conservation Research (Compiled for Latin-American trainees), by L. L. Harrold and D. B. Krimgold, Soil Conservation Service (Research) USDA. A condensed reference on the subject.

Drying Hay by Forced Circulation of Air, by A. T. Hendrix and G. E. Zerfoss. Special Report No. 34, Tennessee Valley Authority (Knoxville, Tenn.). A progress report devoted particularly to experiments conducted in 1946.

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Alexander, G. R.—Division rural service engineer, Alabama Power Co., Birmingham, Ala.

Aspinwall, C. P.—Farm service consultant, Puget Sound Power & Light Co. (Mail) 633 N. DesChutes Way, Tumwater, Wash.

Bell, O. H.—Manager, Pacific Tractor & Equipment, Ltd., 505 Railway St., Vancouver, B. C., Canada.

Berge, Orrin I.—Extension agricultural engineer, University of Wisconsin, Madison, Wis.

Birney, William S.—Supervisor, design service, market development div., Carnegie-Illinois Steel Corp., Carnegie Bldg., Pittsburgh, Pa.

Bornstein, Joseph—Graduate assistant in agricultural engineering, Michigan State College, East Lansing, Mich. (Mail) B-15 Wells Hall.

Cargill, Burton F. J.—Agricultural engineering dept., Michigan State College, East Lansing, Mich.

Chandra, Kailash—Surveyor, engineering department, Agricultural Institute, Allahabad, U. P., India. (Mail) c/o Mr. Rajendra N Pahalwan.

Creasy, Lawrence E.—Associate in agricultural engineering research, Louisiana State University, Baton Rouge 3, La.

Edwards, W. R.—317 E. Broadway, Sulphur Springs, Tex.

Facer, Grant T.—Engineer, Permanente Products Co. (Mail) 421 South 1st Ave., Sandpoint, Idaho.

Flentie, John L.—Project engineer on design, Allis-Chalmers Mfg. Co. (Mail) La Crescent, Minn.

Forbes, David M. L.—Consultant agriculturist, flame cultivation and potato harvesting divs., New Holland Machine Co., New Holland, Pa.

Haynes, B. C., Jr.—Graduate student in agricultural engineering, University of Georgia, Athens, Ga. (Mail) Box 577, Agricultural Hill.

Hickman, K. M.—Sales engineer, Link-Belt Company. (Mail) 220 S. Belmont Ave., Indianapolis, Ind.

Ingram, Troy L.—Junior agricultural engineer, Alabama Power Co. (Mail) R. R. No. 1, Oneonta, Ala.

Krebs, Marion G. — Assistant to general sales manager, John Deere Plow Co. (Mail) 215 S. E. Morrison, Portland, Ore.

Leavitt, Edward T.—Editor, "Tractor Farming," International Harvester Co., 180 N. Michigan Ave., Chicago 1, Ill.

Licht, Ernest F.—Junior project engineer, Lavers Engineering Co., 222 W. Adams, Chicago 6, Ill.

Lucid, F. J.—President, Mobile Equipment Corp., 1010 Vermont Ave., Suite 920, Denrike Bldg., Washington, D. C.

Lura, Loren E. — Engineer, Lavers Engineering Co., 222 W. Adams St., Chicago 6, Ill.

Maneval, Glenn R.—Engineer, consultant in refrigeration, V. C. Patterson and Associates. (Mail) 445 Gantt St., Newport, Pa.

McClarty, Kenneth—Manager, W. R. Rowe Farms, Hollycrest Div., R. R. No. 2, Box 69, Olympia, Wash.

McConkey, Richard K. — District manager and sales engineer, Timken Roller Bearing Co., 715 N. Van Buren St., Milwaukee, Wis.

McCurdy, M. H. — Chief engineer, Cockshutt Plow Company, Ltd., Brantford, Ont., Canada.

Nevin, Earl—Assistant implement and tractor sales manager, Dearborn Motors Corp., 15050 Woodward Ave., Detroit, Mich.

Norton, John S.—Research associate in agrigultural engineering, Louisiana State University, Baton Rouge, La.

Rusco, Easborn — Farm implement design engineer, Lavers Enginering Co., 222 W. Adams St., Chicago 6, Ill.

Schleider, Herbert E. — Instructor, Washington County Veterans Vocational School, Brenham, Texas. (Mail) R. R. No. 1, Box 14.

Slavens, Wayne E.—Engineer, John Deere Des Moines Works, Des Moines, Iowa. (Mail) 415 East 26th St.

Towne, E. Louis, Jr. — Sales manager for California, Thos. W. Allen Co. (Mail) 112 Navone St., Vallejo, Calif.

Tsai, C. H.—Rice Motel, 1558 S. El Dorado St., Stockton, Calif.

Umstadter, H. W.—President, Sunset Enginering Co., Hamburg Turnpike, Riverside, N. J.

TRANSFER OF GRADE

Chugani, G. K. — Ministry of Education, Government of India. (Mail) Eastern Electric & Trading Co., 23-E Connaught Place, New Delhi, India. (Associate to Member)

Cline, Kermit R.—Manager, farm and home appliance dept., Cooperative Seed & Farm Supply Service, Inc., 7th and Main, Richmond, Va. (Junior Member to Member)

Newell, Joseph C.—Insructor and assistant agricultural engineer, University of Arkansas, Fayetteville, Ark. (Junior Member to Member)

Pomerene, Walter H.—Agricultural engineer, Soil Conservation Service, USDA. (Mail) Coshocton, Ohio. (Associate to Member)

Wessman, John H.—Farm practice research section, International Harvester Co., 180 N. Michigan Ave., Chicago 1, Ill. (Junior Member to Member)

FOX

One of the fine things of this world....

"WE believe that you can buy common things and fine things in this world. One man chooses the common, and gets a fleeting satisfaction for having paid so little. Another chooses the finest, and gets the lasting satisfaction and the better bargain for having paid so little more for so much more."

- **You can mow, chop and load, in one operation, over 200 tons of grass silage a day.**
- **You can cut corn of any height, chop it into silage and load into wagons ready for the silo, all in one operation.**
- **One man can pick up, chop and load, ready for the mow or stack, 2 tons of dry hay in 12 minutes.**

Any of the many enthusiastic users of the Fox Forage Master could have written the above quotation. For the Fox Forage Master has saved them much sweat and backache on the three hardest jobs of farming, haying, forage harvesting, and silo filling. Built by the Pioneers of Modern Forage Harvesting and backed by over ten years of successful field operation, the Fox Forage Harvester together with the Fox Crop Blower takes the backaches out of haying and silage making.

Write us today. We will be glad to tell you all about this marvelous machine.

R. C. Krueger, Secretary

FOX RIVER TRACTOR COMPANY

Pioneers of Modern Forage Harvesting

1838 N. Rankin Street

APPLETON FOX WISCONSIN

Personals of A.S.A.E. Members

(Continued from page 130)

Charles L. Seal recently left the employ of the Southern Ford Tractor Corp. as district supervisor, and purchased the Ford tractor dealership at Woodville, Miss.

C. Edwin Smith recently received appointment as an instructor on the teaching staff of the agricultural engineering department of Ohio State University. He was previously employed in the sales promotion department of J. I. Case Co.

C. T. Sturdivant, who is on leave from his position as extension agricultural engineer, Oklahoma A. & M. College, and who for a time served as farm machinery specialist for UNRRA in China, is now serving as irrigation and drainage specialist for the Food and Agriculture Organization of the United Nations in China. In this work he is assisting the Chinese Ministers of Agriculture in setting up and putting into operation a part of the several thousand centrifugal pumps that were furnished to China by the participating nations of UNRRA.

Leo T. Wendling, Jr., is now engaged as extension agricultural engineer at Kansas State College and is specializing in the field of farm structures.

Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings, is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail. For further information see the issue of AGRICULTURAL ENGINEERING indicated.

Attention is invited to the desirability of checking on the housing situation when considering a new location.

POSITIONS OPEN: 1947 MARCH—O-543. APRIL—O-552. MAY—O-564. JUNE—O-569, 571. AUGUST—O-579. SEPTEMBER—O-581, 582. OCTOBER—O-588, 589. NOVEMBER—O-592, 593, 596. DECEMBER—O-597, 598, 599, 600, 601, 602, 603, 604. 1948 JANUARY—O-605, 606. FEBRUARY—O-607, 608.

POSITIONS WANTED: 1947 FEBRUARY—W-373. APRIL—W-389. MAY—W-398, 101, 103. JUNE—W-106. SEPTEMBER—W-119, 120. NOVEMBER—W-126, 128. DECEMBER—W-129, 133. 1948 JANUARY—W-135, 136, 137. FEBRUARY—W-138, 139, 141, 142, 143, 144.

NEW POSITIONS OPEN

AGRICULTURAL ENGINEER (assistant instructor) for farm structures work in large university agricultural engineering department in Midwest. BS deg in agricultural engineering, or equivalent. Student assistant or similar experience desirable. Must be neat, cooperative, interested in students and their problems, and have a church affiliation. Opportunity to complete work for MS deg in six quarters. Age 21 or over. Salary open. O-609

AGRICULTURAL ENGINEER for research in rural electrification, with particular attention to refrigeration, in large university agricultural engineering department in Midwest. BS and MS deg in agricultural engineering or equivalent. Commercial, teaching, or research experience desirable. Must be neat in appearance, cooperative, aggressive, with sense of humor and interest in church and community enterprises. Good opportunity for advancement. Age, 25-30. Salary open. O-610

AGRICULTURAL ENGINEER to develop and initiate practical early steps toward mechanization and increased productive efficiency on small scale farms in China. Young man with BS deg in agricultural engineering, or equivalent, and experience with farm equipment in actual farming operations. Must be adaptable to almost entirely new environment. Opportunity for travel, experience, and exercise of high degree of individual initiative and imagination. Good living quarters provided. Up to $4500 (US), plus maintenance and travel expense. O-611

NEW POSITIONS WANTED

AGRICULTURAL ENGINEER desires development, research, or teaching work in power and machinery or soil and water field. BS deg in agricultural engineering, Pennsylvania State College, 1939. Experience in teaching (four semesters), as farm mechanic on large cranberry and blueberry farm, 1½ years, and as agricultural engineer in soil conservation department of large scale truck farm, 3 years. No disability. Available now. Married. Age 30. Salary open. W-145

AGRICULTURAL ENGINEER desires teaching, extension, research, development, or project engineering in private industry or public service. BS deg in general agricultural science, University of Hawaii. More than 20 years experience in various phases of tropical agriculture and related activities, mostly in executive capacity. No disability. Available now. Married. Age 49. Salary $5400. W-146

(Continued on page 136)

Jamesway

TRADE MARK REG.

barn equipment saves me at least

2 HOURS A DAY

says W. T. McNALLY, Milton, Wis.

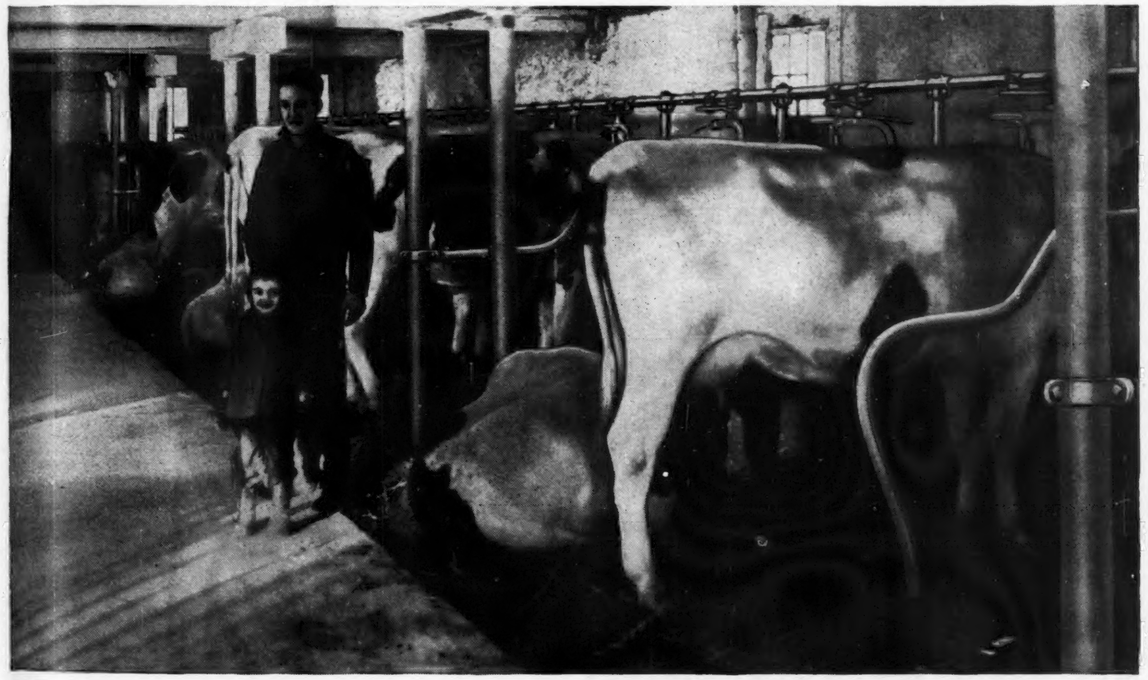
THAT'S right! Two hours of hard, back-breaking work eliminated every day. *Gained instead* — two extra hours of freedom. Plus bigger milk checks. Here's how it was done:

"We remodeled our barn in 1945," Mr. McNally says. "We made it 40 feet longer and installed Jamesway stalls, pens, water cups and ventilators.

"My Jamesway equipment is saving 2 hours a day. In winter this is true of water cups alone. I have 160 acres under cultivation and milk 24 cows — doing all the work without hired help. I believe one man can handle *one-third* more cows with Jamesway equipment and water cups compared to old wood stanchions."

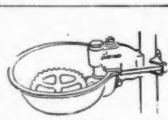
Today it's expensive to do chores the hard way! Modernize your barn with Jamesway — and turn your time into *extra* profits.

All set to start chores are W. T. McNally and his young son. Note how neat and clean they keep their Jamesway equipped barn.

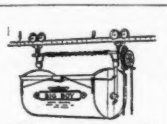


✓ Check this Jamesway Chart to See How Much Time You Can Save Every Day

☐ Save up to 40 minutes with Jamesway feed truck.



☐ Save up to 30 minutes with Jamesway water cups.



☐ Save up to 50 minutes with Jamesway litter carrier.

☐ Save time and feed with Jamesway hog feeders.

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EQUIPMENT & HOUSING
Jamesway
MORE MILK EGGS MEAT
DEALER

For information on the complete line of Jamesway Chore Savers write Dept. A-348

James Manufacturing Company
ELMIRA, N. Y. FT. ATKINSON, WIS. OAKLAND, CALIF.

Look for the Store with the Jamesway Sign.

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FRANK J. ZINK ASSOCIATES
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Consultants on product development, designs, research, market research, public relations
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MEMBER S.A.E.   Telephone: Harrison 0723   Chicago 4, Illinois

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RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

PERSONNEL SERVICE BULLETIN

(Continued from page 134)

AGRICULTURAL ENGINEER desires service work in power and machinery, rural electrification, or soil and water field in private industry; college extension or assistantship with opportunity to study for advanced degree. BS deg in agricultural engineering, Michigan State College, expected March 1948. Dairy farm background. Ten per cent disability due to war injury, no handicap to effective work. Available April 1. Married. Age 31. Salary open. W-147

RURAL SERVICE MAN desires new connection in electrification or design and development of power and machinery. Two years as farm department representative of Central Vermont Public Service Co. Previous experience, 4 years as machinist and metalsmith; 3 years in planning, methods, and design work in machine and metal manufacturing field. No disability. Available May 1, due to reduction in all departments of company forced by flood disaster. Married. Age 34. Salary $4500. W-148

AGRICULTURAL ENGINEER desires design, development, sales, or service work in power and machinery, soil and water, or product processing field, in private industry or public service. BS deg in agriculture, with joint major in agricultural engineering and commerce. Experience as chemical and metallurgical assistant, Nash-Kelvinator Corporation, 20 months, plus limited part time work as student assistant in agricultural engineering. War service as fighter pilot, Air Corps. No disability. Available now. Married. Age 29. Salary open. W-149

AGRICULTURAL ENGINEER desires work in soil and water field with private industry; or sales work in power and machinery field. BS deg in agricultural engineering, Oklahoma A. & M. College, February 1947. One year as student instructor and 6 mo as full time instructor, teaching soil and water conservation in land grant college. Survey work, 6 mo, U. S. Engineer Corps. Commissioned war service, 4½ yrs, Corps of Engineers, with advancement to Lieutenant Colonel. Present employment, senior instructor, veterans on-the-farm training. No disability. Available on reasonable notice. Married. Age 30. Salary open. W-150

RURAL SERVICE MAN desires new connection in rural electrification, preferably with utility. Three years college training in agriculture, Cornell University. With large farm supply cooperative three years, including two years as manager of fertilizer plant. Present employment 2⅓ years, as farm department representative, Central Vermont Public Service Co. No disability. Available May 1, due to reduction in all departments of company forced by flood disaster. Married. Age 26. Salary $3500. W-151

AGRICULTURAL ENGINEER desires drainage, irrigation, or soil conservation work, preferably west of the Mississippi River. BS deg in civil engineering, with major in agricultural engineering, University of Wisconsin, expected July 1948. Illinois farm background. War service in Army Air Force. Part time work as undergraduate assistant in agronomy. No disability. Available July 1. Married. Age 21. Salary open. W-152

SPECIAL NOTICE

The Central Vermont Public Service Corporation wishes to announce the availability of several trained Rural Service Men.

Because of very heavy losses resulting from a flash flood last June, which the Red Cross classes as the third most serious disaster in the United States in 1947, drastic cuts must be made in Company operating expenses to maintain a sound cash position. Farm department personnel along with other departments must be reduced.

Any utility looking for exceptionally well trained and competent men for field work in rural electrification or to organize a Farm Department contact Ralph J. Bugbee, Director of the Farm Department, Central Vermont Public Service Corporation, 121 West Street, Rutland, Vermont.